Canadian
Industry
Program for
Energy
Conservation

CIPEC

Energy Efficiency Planning and Management Guide

Natural Resources Canada
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Canada

Leading Canadians to Energy Efficiency at Home, at Work and on the Road

The Office of Energy Efficiency of Natural Resources Canada
strengthens and expands Canada's commitment to energy efficiency
in order to help address the challenges of climate change.

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preface

The purpose of this Guide is to stimulate thinking about the ways energy efficiency-enhancing measures could be implemented in a plant and to help put these measures in place.

Canadian industry is under increasing economic pressure, the result of working to correct the environmental impacts of production processes (an obligation that raises product costs) while struggling to compete in a global market of falling product prices. To help industry meet this double challenge, the Canadian Industry Program for Energy Conservation (CIPEC) is issuing this new edition of the *Energy Efficiency Planning and Management Guide*, produced by the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan). First published in 1981 and revised in 1993, this edition of the Guide was extensively rewritten and updated with the newest information available at the time of printing.

Reflecting the 27 years of energy efficiency experience, the 2002 edition of the *Energy Efficiency Planning and Management Guide* focuses on reducing energy-related greenhouse gases and – through profit-enhancing energy efficiency measures – on improving the competitiveness of Canadian industry, issues first covered in the 1993 edition.

Part 1 reflects changes in programs offered by utility companies and all levels of government. The chapter on energy auditing has been expanded. In addition, sources of available assistance such as programs and contacts have been updated and expanded and include e-mail and Internet addresses.

Please note: Every effort has been made to obtain the most up-to-date contact information possible.

Part 2 covers many aspects of industrial energy management. It has also been enhanced with knowledge gained from progress technology made since 1993. New energy efficiency developments and recent innovations are mentioned, including some of the ideas from Canada's Energy Efficiency Awards competitions in 1999 and 2000. The energy management opportunities shown in individual sections of the Guide list these ideas.

Improving energy efficiency can be a highly creative and satisfying process, for example when applying a solution known in one field to another. This Guide should facilitate that process. Naturally, the very broad subject of energy management and energy efficiency far exceeds the extent of this Guide. For reasons of space, the various topics are dealt with only briefly. Nevertheless, every effort has been made to assist the reader by giving directions to other sources of information, in all forms, throughout the Guide.

Several sections of Part 2 recommend manuals from NRCan's Energy Management Series. The following titles are currently available:

- *Process Insulation* (M91-6/1E)
- *Energy Accounting* (M91-6/04E)
- *Boiler Plant Systems* (M91-6/6E)
- *Process Furnaces, Dryers and Kilns* (M91-6/7E)
- *Steam and Condensate Systems* (M91-6/8E)
- *Heating and Cooling Equipment (Steam and Water)* (M91-6/9E)
- *Heating, Ventilation and Air Conditioning* (M91-6/10E)
- *Refrigeration and Heat Pumps* (M91-6/11E)
- *Water and Compressed Air Systems* (M91-6/12E)
- *Fans and Pumps* (M91-6/13E)
- *Compressors and Turbines* (M91-6/14E)
- *Measuring, Metering and Monitoring* (M91-6/15E)
- *Materials Handling and On-Site Transportation Equipment* (M91-6/17E)
- *Thermal Storage* (M91-6/19E)
- *Waste Heat Recovery* (M91-6/20E)

Note that these manuals have many worked-out examples of calculations used in implementing various energy efficiency opportunities that can help with projects. The purchase price is $4 per manual + 7% GST. Please make your cheque payable to the Receiver General for Canada. To order, fax us or write to the following address:

Industrial, Commercial and Institutional Programs Division
Office of Energy Efficiency
Natural Resources Canada
580 Booth Street, 18th Floor
Ottawa ON K1A 0E4
Fax: (613) 947-4121

The OEE also offers the following products and services:

- case studies on food-and-beverage, metals, non-metals, chemical processes and general industries;
- training workshops;
- information and advice on energy auditing; and
- technical data and training.

Information about these products and services and the contacts are listed in the relevant sections of this Guide.

Finally, the OEE's Industrial Energy Efficiency program produces and distributes *Heads Up CIPEC*, a bilingual, twice-monthly newsletter, in electronic and hard-copy versions, read by more than 2500 subscribers in more than 1300 organizations and which boasts a total readership of almost 10 000. *Heads Up CIPEC* covers client successes, technologies, other product lines of the OEE and other NRCan programs related to energy efficiency.

Heads Up CIPEC can be accessed at **http://oee.nrcan.gc.ca/cipec/ieep/newscentre/newsletter.cfm.**

How to use this Guide

First, read all of the Guide, even though some sections may not apply specifically to your operations. All sections may contain ideas that are easily transplantable to a particular situation. Innovative, imaginative thinking while reading will help. Modern energy management involves many interrelated energy-consuming systems, just as individual sections of the Guide are interconnected by mutual references, and an overall view should be obtained.

There are evaluation worksheets for each energy topic at the end of each section. The worksheets take the reader step by step through your facilities and processes, looking at each aspect with an eye to improving energy efficiency. Readers can add further questions to the evaluation worksheets that are specific to their operations. Experienced users will find Part 2 a valuable review, whereas the novice energy manager should find the self-guiding style of the text useful for completing the evaluation worksheets.

In Appendix C, various other NRCan publications are listed. We strongly suggest reading carefully the list of technical reports and fact sheets that are available. We want industries to succeed!

part 1

Energy efficiency management in the Canadian context

1.1 Climate change

Greenhouse gas emissions and efforts to reduce them

Scientists have determined that the Earth's atmosphere is changing as a result of emissions of greenhouse gases that trap heat in the atmosphere. One key greenhouse gas is carbon dioxide (CO_2), which is emitted primarily from the burning of fossil fuels. Other contributors to global warming are methane (CH_4), nitrogen oxides (NO_x) and halogenated substances. Compared with CO_2, CH_4 has 24.5 times as much global warming potential; NO_2 has 310 times as much; and halogenated substances have 93 to 24 900 times as much. However, CO_2 contributes more to global warming than all these other substances combined. (See Appendix A – Global warming potential of greenhouse gases.)

The precise effects of this change in the atmosphere are not yet known, but more and more people believe that substantial changes in the world's climate and weather patterns, such as the following, are likely:

- Global temperatures could increase, leading to melting polar ice caps, rising sea levels, flooding of low coastal areas and endangering fresh water supplies.
- Weather extremes could become more severe, and precipitation patterns could shift, disrupting essential weather-dependent activities such as forestry, agriculture and hydro-electric power generation.

Such changes would have enormous social and economic consequences and, if action is taken only when extreme effects begin to appear, significant problems may be unavoidable.

The global response

The United Nations has led an international response to this challenge through its *Framework Convention on Climate Change* (the Kyoto Protocol). Canada signed this convention in December 1997, making the following commitments:

- by January 1, 2000, to stabilize its emissions of greenhouse gases at 1990 levels;
- between 2008 and 2012, to reduce its emissions of greenhouse gases by 6 percent of 1990 levels; and
- to keep the United Nations informed about Canada's CO_2 emissions levels and Canadian programs to limit them.

Canadian activities

Canadian energy efficiency efforts in the manufacturing and mining industries show clearly that volunteerism works. Since 1990, the more than 3000 companies involved in the Canadian Industry Program for Energy Conservation (CIPEC) have made important contributions to achieving Canadian goals, especially by decreasing energy intensity and reducing greenhouse gas production. Between 1990 and 1998, Canada's mining and manufacturing companies improved their average annual energy intensity by 1.26 percent. At the same time, although the economy was expanding vigorously, these companies limited the increase of related CO_2 emissions to less than 0.4 percent above 1990 levels by using energy efficiently.

Equally important, investments and efforts designed to improve energy efficiency also helped participating companies to reduce costs and improve profitability, vital components of the business strategy of any successful enterprise. The achievements of CIPEC participants demonstrate that responsible environmental action does not have to be an expense but can contribute significantly to a healthy bottom line.

Through its Office of Energy Efficiency (OEE), Natural Resources Canada (NRCan) has committed itself to deliver new and established energy efficiency initiatives and to foster energy management in Canadian industry. NRCan carries out these activities through voluntary programs, such as the Industrial Energy Innovators Initiative and through partnerships with private sector organizations such as Canada's Climate Change Voluntary Challenge and Registry Inc. (VCR Inc.).

Impact of energy efficiency measures on greenhouse gas emissions

Improved energy efficiency reduces greenhouse gas emissions in two ways:

- Energy efficiency measures for on-site combustion systems (e.g. boilers, furnaces and ovens) reduce emissions in direct proportion to the amount of fuel not consumed.
- Reductions in consumption of electricity lower demand for electricity and, consequently, reduce emissions from thermal electrical power generating stations.

Although the following examples may seem specialized, the method used to calculate emissions reductions applies to any energy management project that reduces consumption of fuel or electricity.

On-site combustion systems

Use the data in Table 1.1 (page 3) and the information on page 4 to calculate the amount of CO_2, CH_4 and NO_x produced by combustion systems in the following example. To perform this calculation for your own facilities, obtain precise data from your natural gas utility.

TABLE 1.1
Greenhouse gas emissions factors – Combustion source

Fuel type	**CO_2**		**CH_4**		**NO_x**	
Gaseous fuels	**t/ML**	**t/TJ**	**kg/GL**	**kg/TJ**	**kg/ML**	**kg/TJ**
Natural gas	1.88	49.68	4.8-48	0.13-1.27	0.02	0.62
Still gas	2.07	49.68	–	–	0.02	0.62
Coke oven gas	1.60	86.00	–	–	–	–
Liquid fuels	**t/kL**	**t/TJ**	**kg/kL**	**kg/TJ**	**kg/kL**	**kg/TJ**
Motor gasoline	2.36	67.98	0.24-4.20	6.92-121.11	0.23-1.65	6.6-47.6
Kerosene	2.55	67.65	0.21	5.53	0.23	6.1
Aviation gas	2.33	69.37	2.19	60.00	0.23	6.86
LPGs	1.11-1.76	59.84-61.38	0.03	1.18	0.23	9.00-12.50
Diesel oil	2.73	70.69	0.06-0.25	1.32-5.7	0.13-0.40	3.36-10.34
Light oil	2.83	73.11	0.01-0.21	0.16-5.53	0.13-0.40	3.36-10.34
Heavy oil	3.09	74.00	0.03-0.12	0.72-2.88	0.13-0.40	3.11-9.59
Aviation jet fuel	2.55	70.84	0.08	2.00	0.23	6.40
Petroleum coke	4.24	100.10	0.02	0.38	–	–
Solid fuels	**t/t**	**t/TJ**	**g/kg**	**kg/TJ**	**g/kg**	**kg/TJ**
Anthracite	2.39	86.20	0.02	varies	0.1-2.11	varies
US bituminous	2.46-2.50	81.6-85.9	0.02	varies	0.1-2.11	varies
CDN bituminous	1.70-2.52	94.3-83.0	0.02	varies	0.1-2.11	varies
Sub-bituminous	1.74	94.30	0.02	varies	0.1-2.11	varies
Lignite	1.34-1.52	93.8-95.0	0.02	varies	0.1-2.11	varies
Coke	2.48	86.00	–	–	–	–
Fuel wood	1.47	81.47	0.15-0.5	0.01-0.03	0.16	8.89
Slash burning	1.47	81.47	0.15	0.01	–	–
Municipal waste	0.91	85.85	0.23	0.02	–	–
Wood waste	1.50	83.33	0.15	0.01	–	–

Abbreviations: t – tonne; kg – kilogram; g – gram; ML – megalitre; TJ – terajoule; kL – kilolitre; GL – gigalitre. (See Appendix B – Energy units and conversion factors.)

Source: *Voluntary Challenge and Registry Program Participant's Handbook*, August 1995, and its addendum, issued in March 1996. Data supplied by Environment Canada.

- When the soaking pit in a steel mill was re-insulated, the original natural gas burners were retrofitted with high-efficiency burners. Annual fuel savings are estimated at 50 terajoules (TJ). What would be the corresponding reductions in CO_2, CH_4 and NO_x emissions?
- The emissions factors for natural gas fuel are CO_2: 49.68 t/TJ; CH_4: 0.13-1.27 kg/TJ; NO_x: 0.62 kg/TJ. A range of 0.13-1.27 kg/TJ has been indicated for CH_4, so we will assume 0.6 kg/TJ for this calculation.

CO_2 reduction = 50 TJ/yr. × 49.68 t CO_2/TJ = 2484 t/yr.

CH_4 reduction = 50 TJ/yr. × 0.6 kg CH_4/TJ = 30 kg/yr.

NO_x reduction = 50 TJ/yr. × 0.62 kg NO_x/TJ = 31 kg/yr.

Process

Using the data in Table 1.2 (page 5) and the information given in the following, calculate the amount of CO_2, CH_4 and NO_x emitted during processing.

- A cement plant improved several of its processing techniques and realized a 10 percent reduction in fuel consumption. Calculate the reduction in CO_2 emissions if the plant's processing capacity is 50 000 tonnes per year.
- The CO_2 emission factor for cement production is 0.5 t/t cement.

CO_2 emissions from plant before improvements:
= 50 000 t/yr. × 0.5 t CO_2/t = 25 000 t/yr.

CO_2 emissions from plant after improvements:
= 25 000 t/yr. × 10% reduction = 22 500 t/yr.

Impact of reductions in electrical consumption

Energy management projects that reduce electrical consumption also have a positive effect on the environment. However, the emissions reductions occur at the electrical generating station rather than at the site of the efficiency improvements. To calculate the emissions reduction, use the method outlined in the preceding, and then calculate the energy saved at the generating station. This is done by adjusting the figure that represents energy saved at the site to account for losses in the electrical distribution system.

Using Table 1.3 and the information given on page 6, calculate emissions reductions. To perform this calculation for your own facilities, obtain precise data from your electrical utility.

TABLE 1.2
Greenhouse gas emissions factors – Process source

	CO_2		CH_4		NO_x	
Process	**t/t**	**t/TJ**	**g/kg**	**t/TJ**	**g/kg**	**kg/TJ**
Cement production	0.50	–	–	–	–	–
Lime production	0.79	–	–	–	–	–
Ammonia production	1.58	–	–	–	–	–
Spent pulp liquid production	1.43	102.10	–	–	–	–
Adipic acid production	–	–	–	–	–	–
Nitric oxide production	–	–	–	–	0.03	–
Natural gas production	0.07	–	2.67	–	–	–
Coal mining	–	–	1.20–16.45	–	–	–
Non-energy use	**t/kL**	**t/TJ**	**g/kg**	**t/TJ**	**g/kg**	**kg/TJ**
Petrochemical feedstock	0.50	14.22	–	–	–	–
Naphthas	0.50	14.22	–	–	–	–
Lubricants	1.41	36.01	–	–	–	–
Other products	1.45	28.88	–	–	–	–
Coke	2.48	86.00	–	–	–	–
	t/ML	**t/TJ**				
Natural gas	1.26	33.35	–	–	–	–
Coke oven gas	1.60	86.00	–	–	–	–
Agriculture	**kg per head/year**		**kg per head/year**		**g/kg**	**kg/TJ**
Livestock	36–3960		0.01–120		–	–
Fertilizer use	–		–		1-50	–
Miscellaneous	**kg/t**		**kg/T**		**g/kg**	**kg/TJ**
Landfills	182		66		–	–

Abbreviations: t – tonne; kg – kilogram; g – gram; ML – megalitre; TJ – terajoule; kL – kilolitre; GL – gigalitre.
(See Appendix B – Energy units and conversion factors.)

Source: *Voluntary Challenge and Registry Program Participant's Handbook*, August 1995, and its addendum, issued in March 1996. Data supplied by Environment Canada.

TABLE 1.3
Average CO_2 emissions for 1998, by unit of electricity produced

	t/MWh	t/TJ
Atlantic provinces	0.25	68.4
Quebec	0.01	2.5
Ontario	0.23	65.2
Manitoba	0.03	8.2
Saskatchewan	0.83	231.7
Alberta	0.91	252.1
British Columbia	0.03	7.4
Nunavut, Northwest Territories and Yukon	0.35	98.5
Canada	0.22	61.3

- At a large manufacturing plant in Saskatchewan, the energy management program involved replacing fluorescent light fixtures with metal halide fixtures and replacing several large electric motors with high-efficiency motors. The total annual energy saving was 33 600 MWh. Calculate the corresponding reduction in emissions.
- Table 1.3 shows that, in Saskatchewan, the average CO_2 emissions from electrical power generation is 0.83 t/MWh.
- Convert to equivalent energy saving at the generating station using a transmission efficiency of 96 percent.

Annual energy savings at generating station:
= 33 600 MWh/0.96 = 35 000 MWh

CO_2 reduction:
= 35 000 MWh/yr. × 0.82 t/MWh = 28 700 t/yr.

1.2 The Canadian Industry Program for Energy Conservation (CIPEC)

The following is CIPEC's mission statement:

> To promote effective voluntary action that reduces industrial energy use per unit of production, thereby improving economic performance while participating in meeting Canada's climate change objectives.

CIPEC has been helping Canadian industry to improve energy efficiency for more than a quarter of a century. It is the most important part of the Industrial Energy Efficiency program at NRCan's OEE. CIPEC is an alliance between industry and the Government of Canada to increase energy efficiency, limit emissions of greenhouse gases and improve the competitiveness of Canadian industry.

CIPEC provides a focus for setting energy efficiency improvement targets and the development and implementation of action plans at the industry sector and sub-sector levels. CIPEC works with industry sector task forces and trade associations to track and report energy efficiency improvements and related reductions in emissions. It works to help the implementation of energy efficiency programs – for example, by publishing this Guide.

Background

Following the first world oil crisis of 1973, the Government of Canada became more and more concerned with energy security, pricing and usage issues. In 1975, it mandated the Department of Energy, Mines and Resources (which became NRCan in 1990) to establish CIPEC. The CIPEC initiative was designed to stimulate and coordinate the voluntary efforts of Canadian industry to improve and monitor energy efficiency and exchange non-proprietary technical information on energy use. It delivered results: the initial 14 industrial sectors, accounting for 70 percent of Canadian industrial use, achieved cumulated energy savings of 26.1 percent per unit of production between 1973 and 1990. CIPEC also helped the energy efficiency effort substantially by publishing and disseminating helpful information on technical improvements and energy management practices. By the end of the 1980s, a deregulated energy market led to a decline in interest in energy efficiency. CIPEC participation waned and the program went into decline.

Two external forces in the early 1990s spurred a revival in interest in CIPEC's promotion of energy efficiency and facilitation facilities: international commitment to control the amount of greenhouse gases produced in Canada and the dramatic increase in worldwide industrial competitive pressures.

In its Green Plan (December 1990), the Government of Canada formulated directives to deal with the environmental impacts of energy use – especially the burning of fossil fuels. Two years later, Canada became a signatory of the Rio Declaration on Environment and Development, pledging to stabilize CO_2 emissions at 1990 levels by the year 2000. As a result, CIPEC modified its approach to industrial energy efficiency to deal with the global warming challenge.

CIPEC already had a list of proud achievements on which to build:

- The 26.1 percent improvement in energy efficiency realized by CIPEC members between 1973 and 1990 represented an ongoing reduction of 30.4 percent in Canada's industrial emissions.
- The industrial energy efficiency network comprised more than 3000 companies.
- It enlisted commitments from companies that represented three quarters of industrial energy use to set targets, develop action plans and implement energy efficiency improvement projects.
- It developed a world-class industrial energy efficiency tracking and reporting system based on energy-per-unit output.

CIPEC's enhanced approach to industrial energy efficiency

Apart from the key activity of setting progressive sector-specific energy efficiency improvement targets and action plans that produced earlier successes in reducing energy use, CIPEC, as part of its plan for the 2000–2010 period, also continues to do the following:

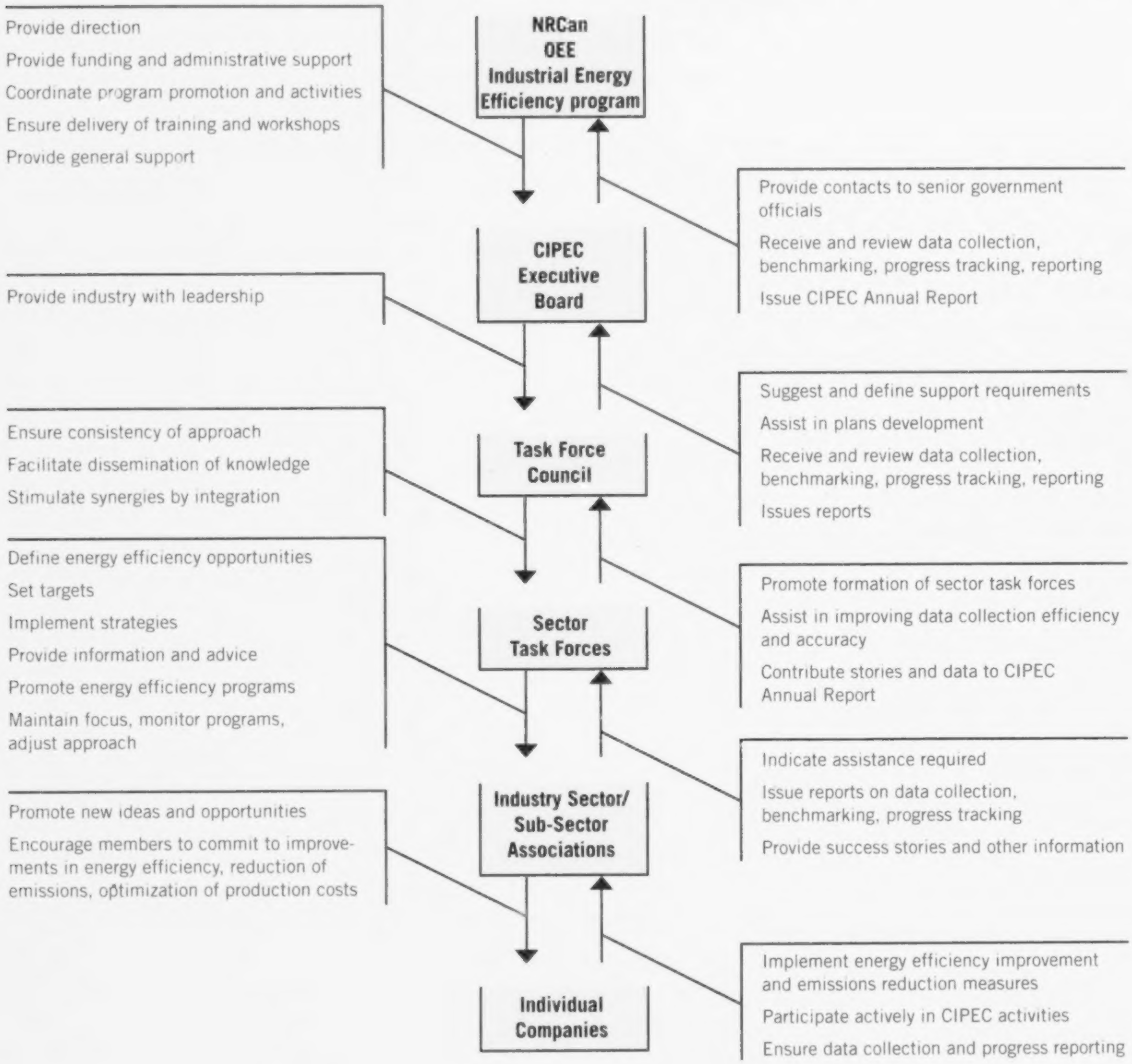
- enlist voluntary commitments from individual companies to improve their energy efficiency and reduce their output of emissions;
- coordinate the establishment of consolidated energy efficiency improvement commitments and individual sub-sector-level targets;
- encourage sub-sector-level implementation of action plans;
- focus on action at the sector level and provide interveners, such as NRCan, with a framework for responding to sector task force recommendations by adapting energy efficiency programs and practices;
- use good data and analyses to track progress;
- consolidate energy efficiency improvements and emissions reduction and report accomplishments;
- use sector task forces to encourage industries to exchange technical information and promote synergy among sectors; and
- encourage, facilitate and provide energy management training.

Current CIPEC organization

CIPEC is a dedicated, cost-effective, proactive organization that concentrates on achieving specific results. It comprises vertical associations, voluntary task forces and companies. It achieves synergy through the Task Force Council of Sector Task Force Chairs (currently more than 20 sectors with 25 task forces supported by more than 40 trade associations and growing). The Task Force Council receives leadership and direction from the Executive Board, many of whose members are on the Board of Directors and Council of Champions of Canada's Climate Change Voluntary Challenge and Registry Inc. (VCR Inc.). See Figure 1.1 on page 9 for the basic structure of the program.

The Industrial Energy Efficiency program provides CIPEC with financial and in-kind support, including administrative services. NRCan is the principal fund-provider as well as its program manager. CIPEC also receives financial and in-kind support from other levels of government and utility companies. Participant companies and associated vertical associations provide in-kind support as well.

FIGURE 1.1
CIPEC's structure (simplified)


NRCan
OEE
Industrial Energy
Efficiency program
Provide direction
Provide funding and administrative support
Coordinate program promotion and activities
Ensure delivery of training and workshops
Provide general support
Provide contacts to senior government officials
Receive and review data collection, benchmarking, progress tracking, reporting
Issue CIPEC Annual Report
CIPEC
Executive
Board
Provide industry with leadership
Suggest and define support requirements
Assist in plans development
Receive and review data collection, benchmarking, progress tracking, reporting
Issues reports
Task Force
Council
Ensure consistency of approach
Facilitate dissemination of knowledge
Stimulate synergies by integration
Promote formation of sector task forces
Assist in improving data collection efficiency and accuracy
Contribute stories and data to CIPEC Annual Report
Sector
Task Forces
Define energy efficiency opportunities
Set targets
Implement strategies
Provide information and advice
Promote energy efficiency programs
Maintain focus, monitor programs, adjust approach
Indicate assistance required
Issue reports on data collection, benchmarking, progress tracking
Provide success stories and other information
Industry Sector/
Sub-Sector
Associations
Promote new ideas and opportunities
Encourage members to commit to improvements in energy efficiency, reduction of emissions, optimization of production costs
Implement energy efficiency improvement and emissions reduction measures
Participate actively in CIPEC activities
Ensure data collection and progress reporting
Individual
Companies

1.3 Setting up and running an effective energy management program

Energy should be viewed as any other valuable raw material resource required to run a business – not as mere overhead and part of business maintenance. Energy has costs and environmental impacts. They need to be managed well in order to increase the business' profitability and competitiveness and to mitigate the seriousness of these impacts.

All organizations can save energy by applying the same sound management principles and techniques they use elsewhere in the business for key resources such as raw materials and labour. These management practices must include full managerial accountability for energy use. The management of energy consumption and costs eliminates waste and brings in ongoing, cumulative savings.

1.3.1 Strategy considerations

The purpose of this chapter is to convince upper management of the value of systematic energy management in achieving the organization's strategic objectives.

In essence, the strategic goal of most corporations is to gain a competitive advantage by seizing external and internal opportunities so as to improve the profitability of their operations, products and sales and their marketplace position. Developing a successful corporate strategy requires taking into account all of the influences on the organization's operation and integrating the various management functions into an efficiently working whole. Energy management should be one of these functions.

In the process, an organization may wish to first conduct a review of its strengths, weaknesses, opportunities and threats (SWOT analysis) that would also include various legal and environmental considerations (such as emissions, effluent, etc.).

Inevitably, this analysis would identify future threats to profitability, and ways to reduce costs should be sought. Energy efficiency improvement programs should, therefore, become an integral part of the corporate strategy to counter such threats. They will help to improve profit margins through energy savings. Applying good energy management practices is just as important to achieving these savings as the appropriate process technology. It should be remembered that any operational savings translate directly to bottom-line improvement, dollar for dollar.

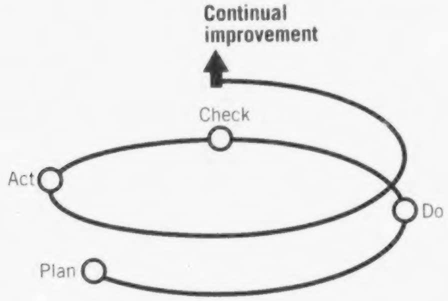
With concern for the environment currently increasing, it is likely that energy efficiency improvement programs would be driven by the company's environmental policy. They would become a part of the organization's overall environmental management system. This would ensure that energy issues would be raised at the corporate level and receive proper attention.

Examples of the benefits of a consistent and integrated approach to achieving energy savings are prevalent throughout the world. Often, production can be increased without using extra energy if existing technologies have been managed within a company's energy management scheme. That scheme should form an integral part of the company's quality and environmental management systems, providing a comprehensive tool for managing and implementing further savings.

The integration of energy into the overall management system should involve evaluation of energy implications in every management decision in the same way as economic, operational, quality and other aspects are considered.

1.3.2 Defining the program

Setting up an effective energy management program follows proven principles of establishing any management system. These principles fit any size and type of organization. As defined by Dr. W. Edwards Deming, the process should have four steps:



These steps, broken down, require several essential activities (see Figure 1.2, next page).

The points depicted in the diagram are generic. As each of the energy efficiency improvement programs is site-specific, the actual approaches to their development will vary.

The following brief examination of these individual points will provide a simplified blueprint to energy management program implementation.

1.3.3 Energy management program – How to implement it

Obtain insight

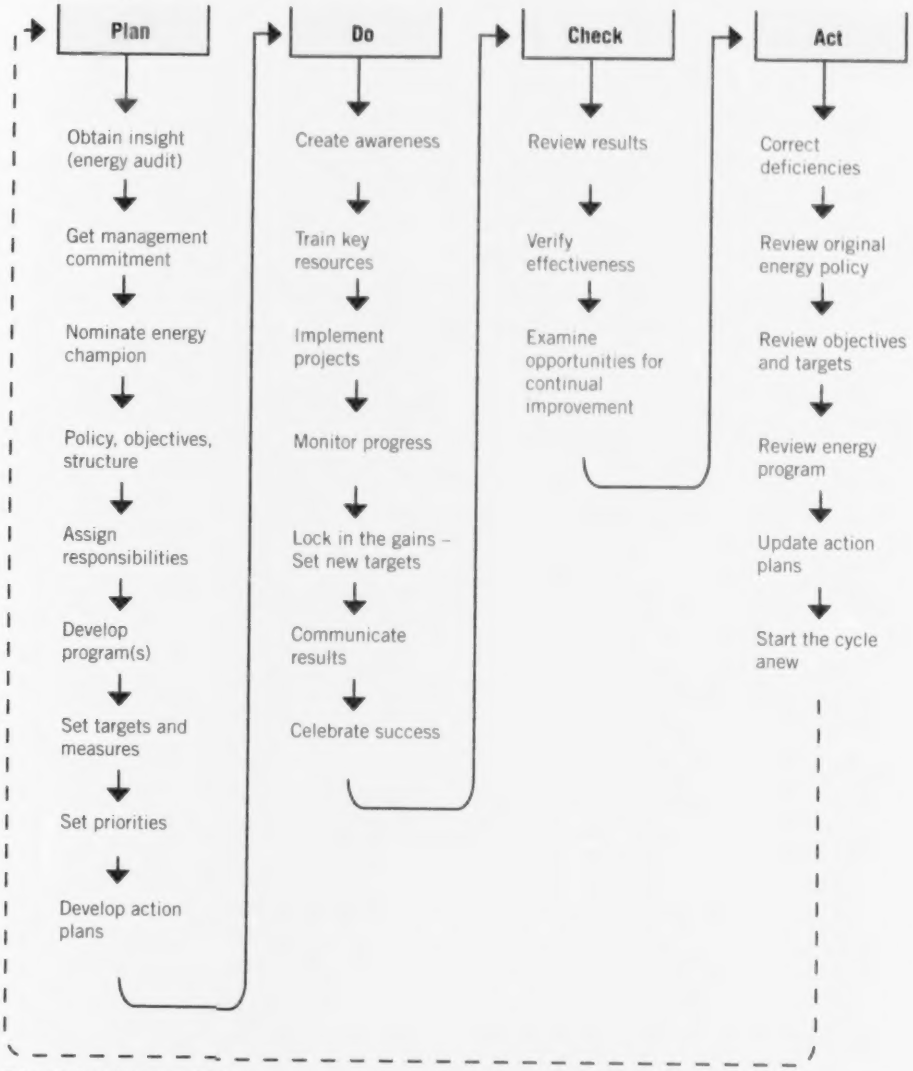
The first step in implementing an energy management program is the energy audit. It consists of documentary research, surveys (including interviews and observations) and analysis to determine where and how energy is used and may be lost. The energy audit is the cornerstone of the energy management program. This is why an entire chapter in this Guide is devoted to this important subject (see Section 1.4, "Energy auditing," page 24). The energy audit is necessary in order to identify opportunities for energy management and savings. It establishes "ground zero," the base from which the progress and success of energy management can be measured.

Several resources are available to help you conduct the audit and perform the calculations. Experienced auditors require little or no support and can conduct an energy audit on short notice. Most auditors will find Part 2 of this Guide useful. Its technical information will help them to evaluate sources of energy loss and to decide which areas require detailed examination.

More information about available assistance is listed later on in this section.

FIGURE 1.2

Energy management plan at a glance


Plan
Obtain insight (energy audit)
Get management commitment
Nominate energy champion
Policy, objectives, structure
Assign responsibilities
Develop program(s)
Set targets and measures
Set priorities
Develop action plans
Do
Create awareness
Train key resources
Implement projects
Monitor progress
Lock in the gains – Set new targets
Communicate results
Celebrate success
Check
Review results
Verify effectiveness
Examine opportunities for continual improvement
Act
Correct deficiencies
Review original energy policy
Review objectives and targets
Review energy program
Update action plans
Start the cycle anew

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Get management commitment

Energy management must be a matter of concern to everybody in the company before it can succeed. Without strong, sustained and visible support of the company's top management, the energy management program is doomed to failure. Employees will apply their best efforts to the program only when they see that their supervisors are fully committed. Hence, it is crucial that top management rally to the cause and provide full support and enthusiastic participation. Because the program involves everybody, the support of union officials should be secured very early on.

Nominate an energy champion

A senior manager in the role of energy management champion should head the energy management structure. The person will give the program enough clout and stature to indicate to the entire workforce that energy management is a commitment that everyone must take seriously. The champion should demonstrate a high level of enthusiasm and deep conviction about the benefits of the energy efficiency program.

Set energy policy, objectives and structure

The launch of the energy management program should start with a strong policy statement from the chief executive to the employees, followed up immediately by a presentation that explains the benefits of efficient energy use. The energy policy should be developed in step with the company's strategic goals and in agreement with other policies (quality, production, environment, etc.) and the company's vision and mission statements.

In order to give the program legitimacy – apart from showing strong, sustained and visible support – top management must make and keep other important commitments:

- to view the energy management program to be as important as production;
- to provide the resources necessary; and
- to report on progress to shareholders and employees.

The effectiveness of an energy management program depends on the time and effort allowed to be spent by those who are charged with its implementation. Therefore, adequate operational funding is essential.

In setting the objectives, the organization should consider its priorities and its financial, operational and business requirements and make them specific. The objectives should be measurable, realistic and clearly defined and should be communicated to all.

Assign responsibilities

The champion chairs the Energy Management Committee (EMC) and takes overall personal responsibility for the implementation and success of the program and accountability for its effectiveness. The energy champion should have the appropriate technical knowledge and training as well as free access to senior management. Beyond these requirements, the ideal person will have skills in leadership, motivation, communication, facilitating and mediation, persistence, determination and the willingness to advocate for the cause of energy efficiency. The person should also have an excellent follow-through on issues and with members of the EMC.

The other part of the champion's duties is to report regularly and frequently on the status of the energy management program, especially when a project has reached its energy-saving target.

Specific responsibilities and accountabilities for the energy management program may be assigned to area managers. Line managers must also learn why effective energy management is needed and how they can contribute to it. As well, with the concept of energy being a managed resource and its use spanning several operational departments, their managers must be made accountable for its use within their area. That may not happen overnight, though, as monitoring equipment and consumption measurements are not often available at first.

The EMC should include representatives from each major energy-using department, from maintenance, from production operators, as well as from various functions, including finance, purchasing, environment and legal. Members should be prepared to make recommendations that affect their areas and to conduct investigations and studies. Energy management generally works best when specific tasks are assigned and people are held responsible.

In smaller organizations, all management staff should have energy consumption reduction duties.

Develop program(s) for energy efficiency management

A successful approach to developing an energy efficiency improvement program would include the following items:

- a long-term savings plan;
- a medium-term plan for the entire facility;
- a first-year detailed project plan; and
- action to improve energy management, including the implementation of an energy monitoring system.

The last point should also capture the energy savings that will assuredly result from improved housekeeping practices alone. Companies around the world report that these measures alone can save 10 to 15 percent of energy costs merely through the elimination of wasteful practices.

The energy management plan should be ongoing and have a number of energy-saving projects coordinated together, rather than be implemented haphazardly or in a bit-by-bit fashion.

The energy management champion should share with the EMC members all the available information about energy use and challenge them to explore ways to conserve energy in their respective areas or departments.

Using this information, define realistic energy-saving goals that should offer enough incentive to challenge the employees.

Establish a reporting system to track progress toward these goals, with adequate frequency.

Set targets and measures

What you can measure, you can control. Often, there is only rudimentary measuring equipment in place, particularly in smaller facilities. That should not be an impediment to starting an energy efficiency improvement project, however. More gauges, sensors and other equipment can be added as the energy management effort accelerates. In fact, early successes with energy-saving projects will provide strong justification for acquisition of new metering equipment.

Targets should be measurable and verifiable. To ensure that they are realistic, apply standards that indicate how much energy should be used for a particular application. Measure current performance against industry standards or calculated practical and theoretical energy requirements. Wherever possible, attempt to express the targets in relation to the unit of production. Always set targets and standards in familiar energy consumption units (e.g. MJ, GJ, Btu, therms, kWh – for explanation of the units, see Appendix B). Use MJ or GJ (these are preferred, as are all SI units) or Btu units to permit comparison across energy sources.

When a target level is reached and the results level off, the target should be reset at a new, progressive value.

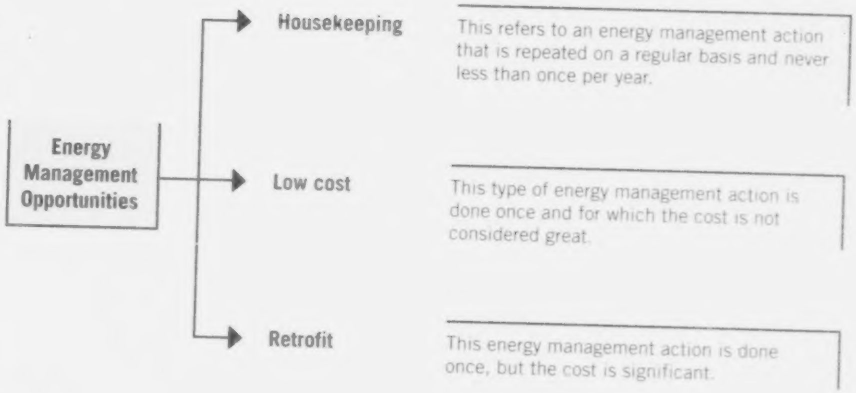
Set priorities

Certainly, do pay due consideration to business needs. But remember that one has to walk before one can run; start with small, easily and quickly achievable targets. That will be a great source of motivation to employees – seeing that it can be done and that progress is being made will lead them to feel that they are successful. As well, EMC members will gain experience and confidence before tackling more complex or longer-horizon targets.

Develop action plans

Be specific – an action plan is a project management and control tool. It should contain identification of personnel and their responsibilities, the specific tasks, their area and timing. It should also indicate specified resource requirements (money, people, training, etc.) and timelines for individual projects and their stages. Several project management software packages are on the market to facilitate the creation of Gantt charts, which are used to monitor and control project fulfilment, costs and other data.

When selecting energy efficiency projects for implementation, look for **energy management opportunities** (EMOs). This term represents the ways that energy can be used wisely to save money. Typically, in most areas, these can be divided into three categories, as seen in the diagram on page 16.



Housekeeping: This refers to an energy management action that is repeated on a regular basis and never less than once per year.

Low cost: This type of energy management action is done once and for which the cost is not considered great.

Retrofit: This energy management action is done once, but the cost is significant.

It should be noted that the division between low cost and retrofit is normally a function of the size, type and financial policy of the organization.

In Part 2 of this Guide, the EMOs will be accompanied by this symbol:

Create awareness

The entire workforce should be involved in the energy efficiency improvement effort. Therefore, everybody should be aware of the importance of reducing energy consumption in bringing about savings, as well as of the broader environmental benefits of energy efficiency improvements – how the reductions in energy use translate into a decrease of CO_2 emissions, for example. Various means can be employed (seminars, quizzes, demonstrations, exhibits) to convey the message. An excellent publication entitled *Toolkit for Your Industrial Energy Efficiency Awareness Program* is available from NRCan (e-mail: indust.innov@nrcan.gc.ca).

A well-executed awareness campaign should optimally result in heightened personal interest and willingness of people to get involved. Employees should know their roles and responsibilities in the overall energy management effort and how their own personal performance can influence the outcome. That should include knowledge of the potential consequences of not improving to the company's and society's well-being.

Creating awareness about the importance of saving energy will help substantially in the implementation of virtually-no-cost energy-saving measures through better housekeeping.

Train key resources

Members of the EMC, line managers and others who will be involved in the energy management program – and have a greater influence upon energy consumption than others – should receive appropriate training. That could include energy-saving practices pertinent to these employees' jobs or essential energy monitoring and measuring techniques. NRCan sponsors a number of specific energy efficiency improvement courses. Other sources of training are available through utility companies and other organizations. For a list of training resources, see pages 21 to 23.

Training can be organized in two stages. The first stage involves specific training for selected employees. The second – following in due course – is a strategy for integrating energy management training into the existing company training matrix in order to ensure that energy training is regularly covered. General team training (e.g. in conflict management and problem solving) should also be provided to the EMC members.

Implement projects

The implementation of energy-saving projects should involve a coordinated, coherent set of projects linked together for the energy efficiency improvement program to be most effective. If several energy projects are contemplated, the interactions between them must also be considered. For example, imagine an office building with two energy management opportunities: installation of high-efficiency boilers and draft-proofing of windows. If the current (pre-boiler conversion) cost of energy is used to calculate payback on the window project, an estimate of 2.4 years results; however, with new boilers, payback on the window project may take 3.1 years.

Start capitalizing on your selected energy management opportunities as soon as possible. Start with projects that yield modest but quickly obtainable savings, especially projects to correct the obvious sources of waste found in the initial energy audit. The savings thus achieved will encourage the EMC to seek greater savings in the areas of less obvious energy consumption, such as energy used by machinery and in processes.

Do not overlook the importance of improving energy housekeeping practices in the overall energy management program (see "Create awareness" in the preceding).

During the first six months of an energy management program, a target of 5 percent savings is generally acceptable. A longer first phase, and a correspondingly higher target, may cause enthusiasm to wane. Hence, start with projects that are simpler and bring results quickly to boost the confidence and interest of the EMC members.

Follow up on activities of individuals charged with specific responsibilities and be mindful of the implementation schedule. The energy management champion should meet with the committee regularly to review progress, update project lists, evaluate established goals and set new goals as required. To sustain interest, the EMC should run a program of activities and communications, and the champion should make periodic progress reports to management, reviewing the program and re-establishing support for it with each report.

Monitor progress

By continuously monitoring the energy streams entering the facility and their usage, the EMC can gather much information that will help it assess progress of its program and plan future projects. Energy-use monitoring produces data for activities such as the following:

- determining whether progress is being made;
- managing energy use on a day-to-day basis to make prompt corrections of process conditions that have caused sudden excessive consumption;
- determining trends in energy usage and using that information in the budgeting process;
- calculating the return on investment (i.e. the cost savings achieved from data gathered by the energy monitoring system);
- providing positive reinforcement that helps employees to willingly adopt the new energy-saving practices;
- comparing the results of an implemented energy-saving measure to the projections in order to identify problems with the project's performance and improve techniques for estimating costs and benefits of energy efficiency improvements for future projects;
- tracking the performance of projects in which suppliers made performance guarantees;
- reporting energy improvements accurately to senior management, thus ensuring management commitment;
- setting future energy use reduction targets and monitoring progress toward new goals; and
- selecting areas of the facility for a future detailed energy audit.

In a large facility with many different functions, energy monitoring is done with metering equipment installed at strategic points to measure the flow of energy sources – such as steam, compressed air or electricity – to each major user. Energy performance is then gauged by calculating the amount of energy consumed per unit of production. Measurement expressions in SI units are preferred, as they enable global comparisons (e.g. MJ or GJ used per tonne of steel produced in a steel plant, or kWh per automobile assembled in an automotive plant).

Calculating energy performance helps managers identify wasteful areas of their facility and lets managers take responsibility for energy use in their areas. When monitoring shows that energy consumption is declining as improvements are being made, attention can be turned to the next area of concern.

Lock in the gains – set new targets

Without vigilant attention to energy management, the gains could fade away and the effort could disintegrate. To make the new energy-saving measures stick, pay sustained attention to the implemented project until the measure has become a well-entrenched routine.

Remember that energy management is an issue of technology as well as people. If practices and procedures have been changed as the result of the project, take the time and effort to document it in a procedure or work instruction. That will ensure the future consistency of the practice, as well as serve as a training and audit tool.

Once a target has been met on a sustained basis over a period of several weeks, it is time to review it. It can become the new standard, and a new, progressive target can be set. Target-setting helps to involve the entire workforce in energy projects by giving them goals to achieve. By setting targets in a step-wise, improving fashion, managers will learn to treat energy as a resource that must be managed with attention equal to that for other process inputs, such as labour and raw materials.

Communicate the results

This extremely important step needs to be well executed in order to foster the sense that everybody is a part of the energy management effort. Regular reports taken from the monitored data encourage staff by showing them that they are progressing toward their goals. The emphasis should be on simplified graphical, visual representation of the results – use charts, diagrams or "thermometers" of fulfilment posted prominently on bulletin boards where people can see them. Someone should be in charge of posting the information and updating it regularly. The format and colours may be changed from time to time in order to maintain the visual interest of the information. Stay away from a dry format of reporting – use a representation that people can understand. For example, express savings in dollars, dollars per employee or dollars per unit of production. Show it on a cumulative basis, i.e. how it contributes to the company's profit picture.

Celebrate the success

This is often an overlooked yet very important segment of a program. People crave and value recognition. A myriad of ways can be employed to recognize the achievement and highlight the contribution of teams (rather than the contribution of individuals, which can be divisive!). Giveaways of thematic T-shirts, hats and other merchandise; dinners; picnics; company-sponsored attendance at sporting events; cruises – the possibilities are endless. Celebrating success is a motivational tool that also brings psychological closure to a project. The achievement of a target should be celebrated as a milestone on the way to continual improvement of energy efficiency in the plant.

Review results

In order to keep the energy management issue alive and to sustain interest, regular reporting to the management team is necessary. Energy management updates should be a permanent agenda item of regular operations management review meetings, just as quality, production, financial and environmental matters are. Results of the implemented project are reviewed, adjustments are made, conflicts are resolved and financial considerations are taken into account.

Verify effectiveness

Has the project lived up to the expectations? Is the implemented energy efficiency improvement really effective? Is it being maintained? To support the credibility of the energy management effort, the effectiveness of measures taken must be verified, so adjustments could be made and the future project managed better.

Examine opportunities for continual improvements

Often one project opens the door to another idea. The energy efficiency improvement program is an ongoing effort. The EMC and all employees should be encouraged to examine and re-examine other opportunities for further gains as a matter of course. That is the essence of continual improvement, which should be promoted in the interest of any organization. In some companies, this is a permanent item on the agenda of EMC meetings.

Correct deficiencies

Information gained from monitoring data, from the input from EMC and others, from the review of results and from the verification of the project's effectiveness may indicate that a corrective action is required. The energy management champion is responsible for arranging this action with the EMC team and the personnel from the respective area. The root cause of the deficiency will be determined, and the required corrective action will be initiated. Remember to document it, as necessary. Future energy efficiency projects will benefit from the lessons learned.

Review original energy policy, objectives and targets, energy efficiency improvement program and action plans

These steps ensure the continued relevancy and currency of the energy policy. Objectives and targets support the policy. As they change in time, they must be reviewed to ensure that priorities are maintained in view of present conditions. This review should take place annually or semi-annually.

The energy efficiency improvement program and action plans are "living" documents. Frequent updating and revisions are necessary as old projects are implemented and new ones initiated and as business conditions change. The energy management champion leads that activity. She/he needs to get input from the EMC and others and seek approval of the updates from the management team.

1.3.4 Energy management training assistance

Managers, technical staff and operations staff with energy management responsibilities will need training in energy management skills and techniques. Through the OEE, NRCan currently delivers two major energy management training programs:

- "Dollars to $ense" workshops:
  - Energy Master Plan
  - Energy Monitoring and Tracking
  - Spot the Energy Savings Opportunities
- Energy Efficiency Skills Development Program

"Dollars to $ense"

The "Dollars to $ense" workshops, delivered by the Industrial Energy Efficiency program of the OEE, cover subjects of interest to the industrial sector.

Energy Master Plan

This workshop prepares participants to plan energy efficiency in their respective fields, helps them develop a thorough understanding of energy and gives them a step-by-step guide to reach their objectives.

Energy Monitoring and Tracking

Participants are trained to divide total energy consumption into its logical segments, and the intricacies of each energy segment are explained. It also covers the following:

- what measurements to use for each type of energy;
- what measuring instruments to use;
- how to record energy use;
- techniques for understanding energy use trends and identifying variations from norms; and
- how to identify opportunities to improve energy management, save money and help the environment.

Spot the Energy Savings Opportunities

This workshop shows participants how to identify energy savings opportunities in their own electrical and thermal processes from point of purchase to end-use, covering the following topics:

- a review of energy basics;
- the incremental cost of energy;
- the potential for change in thermal combustion processes;
- end-use inventories;
- the benefits and costs associated with opportunities; and
- preparation for deregulation by recognizing the value of analysing energy consumption patterns.

The workshops are geared to give participants practical, hands-on training to enable them to expertly prepare energy efficiency programs, carry out energy use monitoring and tracking and uncover other opportunities for energy efficiency. They also show where energy consumption can be cut without compromising system performance.

The low-subscription-cost "Dollars to $ense" workshops are delivered continuously across Canada. The teaching approach promises the following:

- coordinated, cost-effective training in all regions;
- sustainable delivery process;
- expertise available in-house and from industry;
- consistently excellent teaching methods; and
- continuing relationship between NRCan's OEE and Canadian industry.

The workshops are designed for experienced industrial and commercial professionals and tradespeople, such as

- plant engineers and operators;
- technicians;
- maintenance supervisors;
- energy managers; and
- gas and electricity utility representatives.

For further information, contact

Industrial Energy Efficiency
Office of Energy Efficiency
Natural Resources Canada
580 Booth Street, 18th Floor
Ottawa ON K1A 0E4
Telephone: (613) 996-2494
Fax: (613) 947-4121

Energy Efficiency Skills Development Program

Training on energy use in buildings in all sectors is delivered through the Energy Efficiency Skills Development Program (EE Skills).

EE Skills training is delivered all over Canada in both official languages, through federal and provincial training programs, energy service companies (ESCos), educational institutions and private training establishments. Designed to promote energy efficiency awareness, disseminate energy efficiency information and encourage energy efficiency education, EE Skills courses cover energy efficiency in buildings and the use of energy from alternative sources such as solar, waste, biomass, geothermal, small hydro and wind.

EE Skills training is intended for professionals and tradespeople with several years of experience in the building industry:

- building engineers and operators;
- technicians;
- maintenance supervisors;
- energy managers; and
- gas and electricity utility representatives.

For further information, contact

Seneca College of Applied Arts and Technology
1750 Finch Avenue East
Toronto ON M2J 2X5
Telephone: (416) 491-5050, ext. 5050 or 1 800 572-0712 (toll-free)
Web sites: http://senecac.on.ca and http://www.senecac.on.ca/parttime

Seneca College is allied with the OEE and members of an eight-country consortium that is developing an international energy-training network.

Information about the OEE and its various programs is available on the Internet at http://oee.nrcan.gc.ca.

The programs are listed at http://oee.nrcan.gc.ca/english/programs.

1.4 Energy auditing

Previous sections explained that obtaining insight through an energy audit usually precedes the establishment of an energy efficiency program. Indeed, it is the key step that determines the current situation and the base on which energy efficiency improvements will be built. However, an energy audit can also be performed at any time during the program's life to verify results or uncover other energy efficiency opportunities.

As with any other type of audit, the activity can be defined as follows:

> A systematic, documented verification process of objectively obtaining and evaluating audit evidence, in conformance with audit criteria and followed by communication of results to the client.

Naturally, in a general energy audit the focus and the techniques used are intended to get the picture of energy balance in a facility – the inputs, uses and losses. More focused and detailed audits (diagnostic audits) may be carried out to verify the conclusions of a general audit or to get a detailed analysis of energy use and losses in a specific process or facility. Diagnostic audits will be described later on.

The general energy audit comprises four main stages:

- Initiating the audit
- Preparing the audit
- Executing the audit
- Reporting the audit results

These four steps have several sub-steps with associated activities and are shown in a graphical representation on Figure 1.3 (page 25).

The steps shown on the diagram apply to a formal energy audit in a large, complex facility. The applicability is the same whether an organization is performing the energy audit with in-house resources or whether an outside consultant has been hired to do the audit. The audit structure has been designed as a step-by-step, practical guide that can be easily followed, even by those who have not previously been exposed to energy auditing.

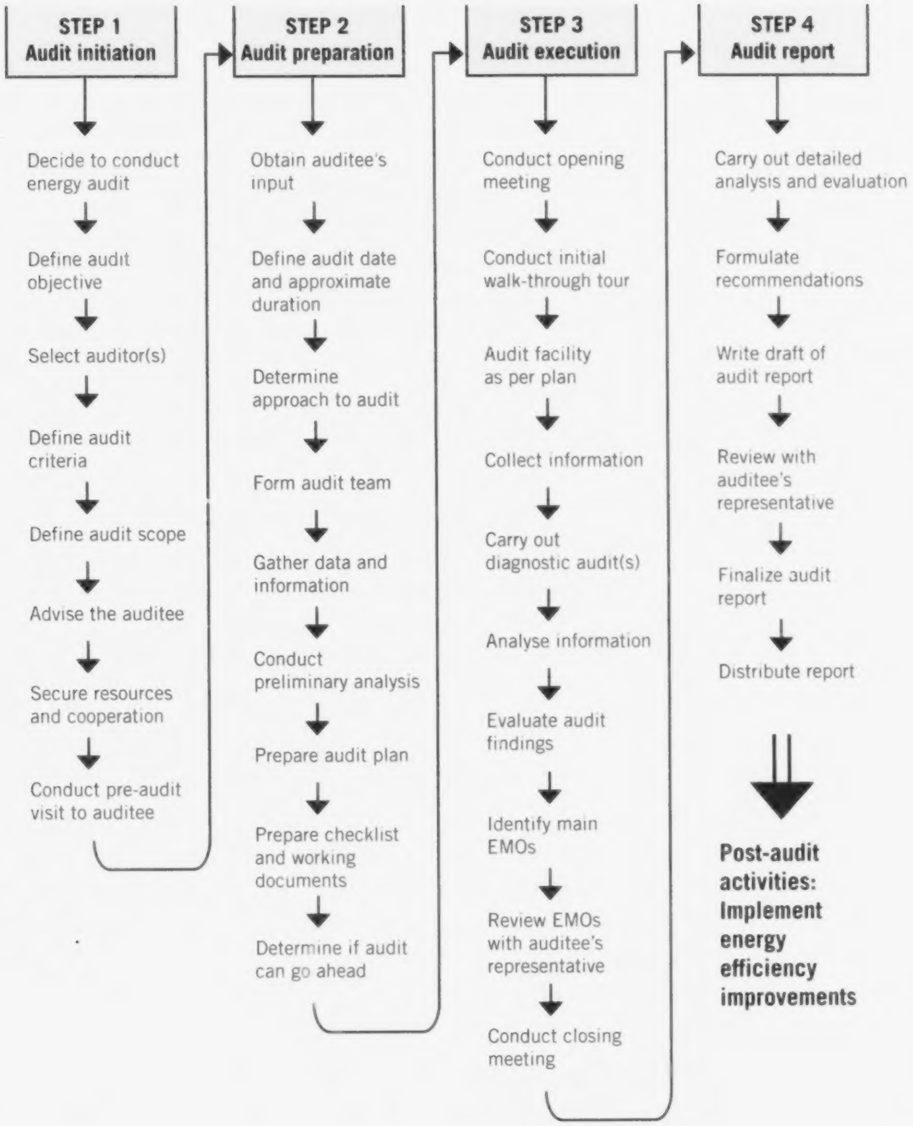
For smaller organizations with limited resources, an experienced manager can take shortcuts through this audit outline and modify it, simplifying the process, to fit his/her particular circumstances.

1.4.1 Audit initiation

Decide to conduct an energy audit

Top management of an organization takes this logical first step early in the process of establishing an energy management program. As such, those ordering (commissioning) an audit are in the role of a client and will normally be the recipients of the final audit report. The auditee is the organization to be audited.

FIGURE 1.3
Energy audit step-by-step


STEP 1
Audit initiation
Decide to conduct energy audit
Define audit objective
Select auditor(s)
Define audit criteria
Define audit scope
Advise the auditee
Secure resources and cooperation
Conduct pre-audit visit to auditee
STEP 2
Audit preparation
Obtain auditee's input
Define audit date and approximate duration
Determine approach to audit
Form audit team
Gather data and information
Conduct preliminary analysis
Prepare audit plan
Prepare checklist and working documents
Determine if audit can go ahead
STEP 3
Audit execution
Conduct opening meeting
Conduct initial walk-through tour
Audit facility as per plan
Collect information
Carry out diagnostic audit(s)
Analyse information
Evaluate audit findings
Identify main EMOs
Review EMOs with auditee's representative
Conduct closing meeting
STEP 4
Audit report
Carry out detailed analysis and evaluation
Formulate recommendations
Write draft of audit report
Review with auditee's representative
Finalize audit report
Distribute report
Post-audit activities: Implement energy efficiency improvements

The selection of an audit site is also done at this point. Choose buildings or areas to cover in the energy audit – these are usually obvious to an outside auditor who has researched the operation with engineering, production and maintenance staff who are familiar with the facility. Outside auditors working in unfamiliar circumstances would use one of the following two methods to prioritize facilities for energy audits:

a) **Priority according to energy consumption:** This method seems most likely to focus on problem areas but is inadequate for operations in which several locations have similar energy consumption profiles or in which process use of energy inflates consumption in particular areas.
b) **Priority according to energy consumption per unit floor area:** This method works well for operations in which facilities of various sizes and types consume energy at similar rates; however, it does not differentiate peak-period energy use from off-peak use, and it treats one-, two- and three-shift operations alike.

Define the audit objectives

Again, it is the role of top management to clearly define one or more objectives of the audit. Consider carefully what the energy audit is to achieve. The objective may be, for example, to identify and quantify energy losses through the building envelope, to point out opportunities for energy efficiency, to verify compliance with the organization's internal energy management policies, or to make specific recommendations for corrective action.

Select auditor(s)

Is there a competent professional in-house? Or is it necessary to hire an experienced outside consultant to do the audit? That decision must be made early, as the auditor needs to be involved right from the start. That person will drive the determination of audit scope and criteria and the rest of the audit preparations.

Note: It is understood that the use of the singular "auditor" in this and the following text is for simplification only; an entire team of auditors may be involved, as appropriate to the circumstances.

The auditor needs not only to be a competent professional but also to be familiar with the auditing process and techniques, particularly that of an energy audit. In the case of an outside consultant, it pays to shop around and get references first.

The energy audit process and its results must be credible. Therefore, key considerations in selecting an auditor are his/her independence and objectivity. This must be both factual and perceived. To assure that, choose an auditor who is

- independent from audited activities, both by organizational placement and as a function of personal goals;
- likely to be free from personal bias;
- known for high personal integrity and objectivity; and
- known to apply due professional care to his/her work.

The auditor's conclusions should not be influenced by considerations of such factors as impact on business units or schedules of production. One way to ensure the independent, unbiased and fresh view of the auditee's operations is to use an independent consultant or staff from different business units.

Define the audit criteria

This step, if applicable, calls for determination of criteria such as policies, practices, procedures or requirements against which the auditor would compare collected audit evidence about the state of energy management in the organization. The requirements may include standards, guidelines, specified organizational requirements and legislative or regulatory requirements.

Define the audit scope

This is another key point. The audit scope describes the extent and boundaries of the audit in terms of factors such as physical location and organizational activities, as well as manner of reporting.

The client must sit down with the auditor and establish the scope of the work. Using the Audit Mandate Checklist (see pages 38 to 41) is a convenient way to complete this essential task.

Set audit boundaries limiting the scope of an audit in a large, complex facility. It may help to visualize the audit boundary as a "black box" enclosing the audit area and then to focus on the energy streams flowing into and out of the box.

For example, when auditing the steam system in a brewery, setting an audit boundary around the bottling plant would mean assessing the efficiency of the steam distribution system in the bottling area rather than calculating boiler efficiency in the powerhouse.

Measurement of these energy flows may play a large part in determining the audit boundary. For example, if the meter system in the facility includes energy used to light the parking lot together with the energy consumed in the associated buildings, the parking lot should be inside the audit boundary. However, the physical boundaries of the audit site are often the most logical audit boundaries.

Wherever possible, start small. Trying to cover too many facilities or processes with a limited number of resources will surely lower the effectiveness of the energy audit.

Other practical considerations in setting the energy audit's scope include the auditee's staff size, the staff's capability and availability, the outside consultant's capability, and money and time available. Attempts to stretch the audit's scope beyond any of these resources may compromise the quality of the audit. Audit quality should never be sacrificed in pursuit of greater geographic scope or new subject coverage.

Advise the auditee

Sometimes the client, who orders the audit, and the auditee (the facility to be audited) are the same entity. Where this is not the case – for example, a large corporation ordering an energy audit in one of its subsidiaries – the auditee should be advised and/or consulted about the forthcoming audit. This is done in the interest of common courtesy as well as to ensure that good communication will help in carrying out the audit successfully.

The auditee should learn about the objectives and should be consulted about the scope of the audit.

Secure resources and the auditee's cooperation

This is another vital component of ensuring that an audit will reach its objectives: a voluntary, ample cooperation of the auditee with the auditor must be secured.

Also, resources should be committed to adequately serve the needs of the intended audit's scope. The allocation of resources to the energy audit should be consistent with its objectives and scope. That includes such things as

- provision of the necessary working space for the auditor;
- assignment of responsible and competent guides to accompany the auditor on her/his rounds;
- unrestrained access to the facilities, personnel, relevant information and records as requested by the auditor;
- facilitation of measurements and data collection; and
- informing the auditor about the organization's health, safety and other such requirements and potential risks.

The auditee should inform employees about the forthcoming energy audit, its objective and scope.

Conduct a pre-audit visit to the auditee

A familiarization visit to the facility before proceeding with other audit preparations serves several purposes: personal contacts and lines of communication are established; a clearer picture of the facility and the scope emerges; issues may be clarified; resources may be identified and secured; and adjustments to the planned audit scope, date and duration may be made.

The auditee is a valuable source of criticism for the audit program. The insights gained can greatly improve the audit process and help to produce better-quality results.

Also, pre-audit questionnaires/checklists may be administered during the pre-audit visit. This will help to minimize the time spent at the site during the actual energy audit and maximize the auditor's productivity. On-site time is costly for both the auditor and the operation being audited.

1.4.2 Audit preparation

Obtain the auditee's input

For an energy audit to be successful it should be approached in the spirit of collaboration. Members of the auditee's staff need to feel that they are participating constructively in the process – that it is not something simply imposed on them. The auditor should consult the auditee about the scope of the audit, seek information regarding areas of concern that need priority consideration and discuss the planned audit methodology, among other tasks.

Define the audit date and approximate duration

With the auditee's concurrence, schedule the audit at the time when

- it is convenient for their operations (e.g. avoid scheduling when staff is away on courses, vacations, during shutdowns and overhauls, etc.); and
- conditions represent typical operational regime and conclusions drawn can reasonably be extrapolated for an entire year.

Determine an approach to the audit

Decide, on the basis of available information, whether the energy survey of the facility will be carried out by examining either

- the entire facility (within the scope of the audit) area by area; or
- the various energy-using systems one at a time.

Also confirm, in accordance with the stated objectives, the extent of work anticipated and the size and complexity of the facility to be audited, whether the energy audit is merely to outline potential energy management opportunities (EMOs), or also includes more detailed, specific diagnostic audits that confirm and quantify these opportunities.

Form an audit team

Once substantial information is available about the facility to be audited, and if the size of the facility warrants it, the appropriate size of the audit team can also be determined. The same criteria that were discussed earlier under the point "Select auditor(s)" also apply for selection of audit team members. The lead auditor (audit team leader) forms the team – giving due consideration to auditors' qualifications and potential conflicts of interest – determines the roles and responsibilities of the individual audit team members, and seeks an agreement on the team's composition with the client.

Gather data and information

The collection of historical data is a critical phase of an energy audit. The reliability of the data is crucial; it directly affects the quality of calculations and of the decisions based on results. Auditors should choose data from the following sources:

- utility bills;
- production records;
- architectural and engineering plans of the plant and its equipment;
- Environment Canada weather records; and
- locally generated company energy consumption records.

The audit team would require utility invoices for all energy sources – electricity, natural gas, fuel oil and water – for at least 12 months, preferably ending at the audit period. To be a reliable baseline from which future energy consumption is to be monitored, the data must represent the facility's current operations.

Production records are required to account for variations in the data gathered from utility bills (e.g. annual shutdowns will show up as reductions in energy consumption lasting one or two weeks). Plans and drawings familiarize the auditors with the facility and help them locate critical energy-using equipment. Plans are also useful for

- calculating floor, wall and window areas;
- identifying building envelope components, such as thermal insulation;
- locating, routing and identifying the capacity of building services; and
- locating utility meters (present and planned).

Equipment capacity data, available from the data plate, are needed to calculate the energy consumption of equipment for which specific meter data are not available. To calculate the energy consumed by a piece of equipment from data plate information, the correct load factor must be determined. The load factor is a fraction of the rated full-load energy consumption that the equipment actually uses.

Weather data (monthly or daily degree-days) are required when the audit examines systems that are influenced by ambient temperatures, such as building heating or cooling equipment. Records kept by building and process operators are useful for explaining short-term process variations, such as steam flows to batch processes.

Conduct preliminary analysis

A preliminary data analysis is performed to assess the overall plant and to establish the scope of the remaining work, including investigation and analysis. The following are the key tasks in the preliminary analysis process:

- reconcile utility data with plant operating information;
- identify the main areas of energy consumption; and
- establish a work plan for gathering information at the audit site, analysing all data and producing an audit report.

Natural gas and electricity bills: Data from invoices for purchases of natural gas and electricity are easy to reconcile with plant process data because the customer is billed only for the amount consumed, and natural gas and electricity are both consumed as they are delivered.

Fuel oil and coal (coke) bills: Because fuel oil and coal are stored on-site, sometimes for long periods, oil and coal bills are of limited use to the auditor unless deliveries are made at least once per month and it is established that, between each of the last two deliveries, the entire amount received at the earlier period was consumed. That, however, is unlikely to happen frequently. Coal consumption can be reliably estimated only from measurements of the combustion efficiency and energy output of coal-fired equipment. Precise oil consumption data can be obtained in facilities where meters are installed on the outflow from oil storage tanks and records of meter readings are kept.

Energy balance: By finding the facility's energy balance, the auditor can see where energy is consumed most and can identify areas to examine closely during subsequent phases of the audit. To obtain the energy balance, follow the plant's energy use as it disintegrates into its constituent components; the results are best illustrated by a Sankey diagram, a pie chart or a bar graph.

Prepare the audit plan

An audit plan is a "living" document that must be flexible enough to permit immediate adjustments to emphasis on account of information gathered during the audit or changed conditions. Nevertheless, an audit plan is a vital planning and communicating tool that ensures consistency and completeness of audit coverage of the subject matter and effective use of resources.

The audit plan should spell out the following:

- details of the auditee (the organizational and functional units to be audited, addresses, contacts);
- dates and places where the audit is to be conducted;
- audit objectives and criteria, if applicable;
- audit scope;
- identification of the energy audit elements that are of high priority;
- expected time and duration for major audit activities;
- identification of audit team members;
- schedule of meetings to be held with the auditee's management;
- confidentiality requirements; and
- audit report content and format, expected date of issue and distribution.

The preparation of the audit plan is the duty of the lead auditor. The plan should be communicated to all parties concerned, i.e. the client (who should approve it), the audit team and the auditee.

Prepare checklists and working documents

Using an audit checklist may be likened to a car driver using a road map: it ensures that the goal will be reached in the minimum amount of time and that no important points of the journey will be missed. Sometimes, instead of "checklist," the term "audit protocol" is used.

Checklist questions, geared to various types of energy-using equipment and physical facilities, are contained in or can be formulated from evaluation worksheets in Part 2 of this Guide. It is well worth the effort to prepare the checklists, no matter how extensive the experience of the auditors. The quality of the audit conclusions will be supported by their use. The checklists provide objective evidence that all relevant aspects were covered. The lead auditor coordinates the preparation of the checklist.

The purpose of a checklist is to stimulate thinking and systematically guide the auditor. The use of a checklist encourages these energy audit steps:

- list the existing measuring, metering and monitoring equipment;
- examine the suitability of the existing equipment;
- examine the function, management and energy performance of systems and processes;
- establish what additional information is needed and the steps to be taken;
- list upgrades that would be useful and help estimate their costs; and
- estimate savings or increased throughput.

Other working documents may include meeting and meeting attendance record forms, audit record forms (auditor's notes), plan of the facility and the like.

The purpose of using all of the above-mentioned checklists and working documents is to ensure a consistent and systematic approach to and execution of an audit. The uniformity aspect is all the more important when an organization wishes to conduct an energy audit of several of its facilities.

Determine if the audit can go ahead

The lead auditor can give a formal go-ahead to the energy audit only when the three following essential conditions for conducting an audit are present:

- adequate resources are available;
- sufficient information is available; and
- auditee's cooperation is secured.

1.4.3 Audit execution

Conduct an opening meeting

The opening meeting sets the tone of the audit. Therefore, it is a very important part of the energy audit.

Spend time and effort on the opening meeting – if the auditee's staff gains confidence about the audit process, they will have confidence in the results, too.

Audit team members and the facility staff meet, perhaps for the first time, so as to

- review the purposes (objectives), scope and plan of the audit;
- make changes to the audit plan as required;
- describe and understand audit methodologies;
- define communications links during the audit;
- confirm availability of resources and facilities;
- confirm the schedule of meetings with the management group (including the closing meeting);
- inform the audit team about relevant site health and safety and emergency procedures;
- answer questions; and
- establish a comfort level between the two groups.

The auditee's staff is encouraged to participate actively in the audit and keep notes on their own observations.

The lead auditor should also point out the limitations of the audit, the chief one being that the examination is based on limited-time observations.

Conduct an initial walk-through tour

The initial walk-through tour of the facility should be done especially for the benefit of the team members who may not have seen the facility before. It helps the orientation and outlines areas of high concern and major issues. These can be revisited for in-depth examination and observation later. Dangerous areas and those that are off limits to visitors will also be pointed out during the initial tour.

Before the tour, and during the subsequent audit proper, ensure that you wear appropriate personal protection equipment (safety glasses, safety shoes, hard hats, hearing protection, respirators, etc.).

Audit facility as per the audit plan

The audit team disperses with their guides to conduct the audit according to the plan. The energy audit may include techniques normally used to gather audit evidence – interviews, gathering objective evidence (records) and observations – complemented by the auditors' own measuring and recording activities, as circumstances dictate. For these activities, ensure that the facility's staff is available to help them.

An audit should be carried out during normal operating conditions. However, to find out about equipment left running or compressed air lines leaks when the facility is not occupied, the auditors should visit the facility during off-hours.

Collect information

During the audit – through interviews and the examination of records and observations – the checklists are used to identify problem areas and EMOs. These are to be examined more closely in subsequent detailed, diagnostic audits.

Carry out the diagnostic audit(s)

A diagnostic audit is done to verify the data collected from plant records and to gather additional information through detailed observations and discussions with plant personnel. This may also include requests for demonstrations and taking additional measurements and recordings. This detailed data gathering helps the auditor detect and account for operational variances, transients and other irregularities. From this information, the achievable energy utilization per discrete item of equipment or system can be calculated on an "as found" basis. It shows the current status that will formulate the basis for justification and subsequent implementation of changes to improve energy efficiency.

Analyse the information; Evaluate audit findings; Identify main EMOs

Toward the close of the audit, all information gathered during the audit is reviewed by the auditors, and tentative findings and observations are formulated. The team, under the lead auditor's guidance, obtains consensus on the draft of main audit conclusions, recommendations and EMOs. If possible, a rough quantification of anticipated energy savings should accompany this stage.

Review the EMOs with the auditee's representative

As the last check, the audit results are briefly discussed with the appointed auditee's representative and agreement secured. This is done both as a courtesy as well as in the interest of time management by limiting the amount of discussion necessary at the closing meeting.

Conduct a closing meeting

This step brings some closure to the audit process on site, although other activities still need to follow. A closing meeting is essentially a communication meeting that serves to present the audit findings and conclusions to the facility's management team. At the end, there should be a clear understanding and acknowledgement of the result. Also at this stage, disagreements should be resolved, if possible. The management team should now have a clear picture, albeit without all the details, of what measures can be put into place to improve operational energy efficiency.

1.4.4 Audit report

Carry out detailed analysis and evaluation

Often, the limited time for on-site audit activities does not allow the auditors to carry out a detailed analysis of the energy audit information. Remember the on-site audit costs issue. At this point in the process, the data collected during the general and diagnostic audits are used to calculate the amounts of energy used in, and lost from, equipment and systems. By calculating the value of this energy, the auditors produce more accurate estimates of the savings to be expected from an energy project. Analysis of the energy surveys will indicate the energy services with the most potential for immediate improvement. A cost-benefit analysis based on future energy costs will show the merit of each potential improvement and help to set priorities.

The least complicated approach to evaluating a potential energy project is to calculate the project's simple payback – that is, the installed costs of the project divided by the annual savings it produces. The result is a figure that represents the number of years it will take for the accumulated savings from the project to equal the cost.

Energy intensity ratios (i.e. energy used per unit of output) should be calculated quarterly or monthly for the entire plant, every operating department and each significant process. The energy intensity ratio will also indicate unfavourable energy consumption trends. In other words, this process lays the foundation for a systematic energy management approach.

Formulate conclusions and recommendations, write a draft of the audit report, and review the draft with the auditee's representative

At this point in the audit process, the selection of EMOs can be confirmed and finalized, with proper cost-benefit evaluations. The audit conclusions and recommendations can now be firmed up and a final report can be drafted. The content of the report should be shared with, and agreed on, by the auditee's representative – for the same reasons that were stated earlier in the context of the closing meeting.

Finalize and distribute the audit report

It is only at this point that the audit report can be finalized. Following that, it can be distributed to the client and the auditee, subject to previously received directives.

1.4.5 *Post-audit activities – Implementing energy efficiency*

The process of key importance – an energy audit – has been concluded. As soon as possible after the audit, the management team should review the results and decide on the course of action to be taken. At this point in the process, the facility is ready to act on EMOs and develop new operating scenarios. What follow then are the steps described previously in Section 1.3, "Setting up and running an effective energy management program" (page 10).

1.4.6 *Audit assistance*

The following sources of information will assist in carrying out an energy audit.

Energex is a software tool developed at West Virginia University with support from the U.S. Department of Energy. It is a useful supplement to the evaluation process set out in this Guide. For information about Energex, contact the address below:

Dr. B. Gopalakrishnan
Assistant Director
Industrial Assessment Center
West Virginia University
P.O. Box 6070
Morgantown WV 26506-6070
U.S.A.

Telephone: (304) 293-4607, Ext. 709
Fax: (304) 293-4970

Energy Audit Software Directory 1997 is an excellent compendium of some 100 energy audit packages, available from international sources. The Industrial, Commercial and Institutional Programs Division of the OEE prepared this directory, which describes functions and hardware requirements, prices and supplier data. Every facet of energy auditing is covered from a multitude of views. Computer software can help auditors with many aspects of an energy audit, from simulating complex processes to analysing energy use data for trends and anomalies. For information, or to obtain a copy of the directory, fax your request to (613) 947-4121.

Other sources of assistance

Plant staff can often perform energy audits. If this is not possible, consultants can help identify opportunities to improve efficiency and save energy. Other energy audit program assistance may be available from some of the following:

- natural gas utilities;
- fuel oil suppliers;
- provincial electricity utilities;
- municipal electricity utilities; and
- private electricity utilities.

Most energy suppliers will also provide advice and guidance for more detailed audits and give information on the latest technologies for improving energy efficiency and reducing emissions. Provincial and territorial energy and environmental departments also provide energy efficiency improvement information. For more information, see Section 1.5 of this Guide, "Assistance for energy management programs and environmental improvements" (page 42).

Audit mandate checklist

Organization: ______________________________

Address: ______________________________

Audit location: ______________________________

Energy audit objective(s): ______________________________

Audit scope – boundaries: ______________________________

Audit criteria: ______________________________

Areas to be examined

- ☐ Entire site
- ☐ Individual buildings (describe): ______________________________
  ____
- ☐ External on-site services
  - ☐ Lighting
  - ☐ Heating
  - ☐ Other (describe): ______________________________
    ____

Individual services

- ☐ Boiler plant
- ☐ Distribution systems
- ☐ Domestic and process water
- ☐ Process refrigeration
- ☐ Production and process operations (describe): ______________________________
  ____
- ☐ Lighting
- ☐ Electrical
- ☐ Heating, ventilating and air conditioning (HVAC)
- ☐ Building envelope
- ☐ Rate structures

Resources

In-house staff

- ☐ Technical
- ☐ Clerical
- ☐ Other (describe): ______________________________

____

External

- ☐ Consultants
- ☐ Utility companies
- ☐ Energy service companies
- ☐ Government organizations
- ☐ Contractors

Details: ______________________________

____

Measuring and monitoring equipment available

Describe: ______________________________

____

Building characteristics

Remaining life of

Building structure: _____ years

Envelope system: _____ years

HVAC system: _____ years

Interior partitions: _____ years

Changes and renovations planned (details): ______________________________

____

Building conditions

Current problems:

- ☐ Comfort
- ☐ Breakdowns
- ☐ Lack of capacity
- ☐ Appearance

☐ Noise

☐ Other (describe): ______________________________

____

Data available

Drawings

☐ None

☐ Some

☐ Comprehensive

Production records

☐ None

☐ Some

☐ Comprehensive

Energy usage records

☐ None

☐ Some

☐ Comprehensive

Investment and operational needs and desires

☐ Save energy

☐ Reduce use of fuel (describe): ______________________________

____

☐ Reduce time systems operating under maximum-demand conditions

☐ Accommodate increased load

☐ Charge energy costs directly to consumers

☐ Reduce requirement for manual operation

☐ Other (describe): ______________________________

____

Will audit recommendations be applied to other buildings?

☐ Yes

☐ No

Explain: ______________________________

____

Deadlines

Audit dates (from, to): ____________________

Date completion required: ____________________

Date preliminary findings required: ____________________

Date final report required: ____________________

Report distribution: ____________________

Implementation

Housekeeping deadlines: ____________________

Low-cost deadlines: ____________________

Financial limits: ____________________

Retrofit deadlines: ____________________

Financial limits: ____________________

Reporting format

Level of detail required: ____________________

Financial analysis required: ____________________

Acceptable payback period: ____________________

Tax advantages

Details: ____________________

____

Grants and subsidies available

Details: ____________________

____

Agreements

Organization's representative, name, title, signature:

____

Date: ____________________

Lead auditor – name, company, signature:

____

Date: ____________________

1.5 Assistance for energy management programs and environmental improvements

Industries that want to evaluate and improve the energy efficiency of their operations have many sources of assistance, including CIPEC (through NRCan's OEE), other federal and provincial agencies, utilities, engineering firms and equipment suppliers.

This section consists of brief descriptions of the types of assistance currently available, with information about contacts where you should be able to get additional information and training, updated to March 2002.

Activities of the Government of Canada

Natural Resources Canada

NRCan consolidated its energy efficiency and alternative fuel programs into the OEE on April 1, 1998. There are currently 17 energy efficiency programs run by the OEE. Of these, the following initiatives apply specifically to industrial energy efficiency:

- the Canadian Industry Program for Energy Conservation (CIPEC); and
- the Industrial Energy Innovators Initiative.

The OEE's Industrial Energy Efficiency program, which runs these two initiatives and is an industry-led, voluntary program to increase the efficiency of energy use in Canada's goods-producing industries.

Recently, the Industrial Energy Efficiency program has published a series of industrial sector-specific guidebooks, *Energy Efficiency Opportunities in… Industry*. To date, guidebooks have been published for the following industries: dairy processing, rubber, brewery, aluminum smelters, solid wood, lime, cement, heaters and boilers, and pulp and paper.

These guidebooks contain current information on energy-saving measures and audit checklists. They are an excellent source of help in setting up an energy management program. These guidebooks can be obtained from the appropriate industry association or from the OEE. Also, benchmarking studies have been sponsored by the OEE and are currently available for the dairy, cement and pulp and paper industries.

The Energy Management Series of technical manuals, available from the OEE, deals with energy use, energy efficiency improvement and energy recovery in all areas of industrial operation. Each manual contains worksheets that are especially useful for calculating energy use and savings for topic-specific projects. Completed samples show how to use the worksheets. Some of these manuals were produced in the 1980s, and many technical advances have been made since then. However, the principles have not changed, and the manuals remain useful for most practical purposes. The list of manuals and contact information are given in the preface of this Guide (see page vi).

Canadian Industry Program for Energy Conservation (CIPEC)

CIPEC, which receives core funding and administrative support from NRCan's OEE, provides industry with a mechanism for obtaining the following types of assistance:

- setting energy efficiency improvement targets for each sector and its sub-sectors;
- publishing reports of accomplishments in energy efficiency improvements;
- encouraging implementation of action plans at the sub-sector level;
- promoting synergy among sectors through sectoral task forces;
- providing a framework for organizations (such as NRCan) to identify and respond to task forces' recommendations for energy efficiency programs and practices at the sub-sector level;
- obtaining commitments to energy efficiency activities from individual companies participating as Industrial Energy Innovators in Canada's Climate Change Voluntary Challenge and Registry Inc. (VCR Inc.);
- giving energy managers a way to share expertise and contribute to the setting and meeting of energy efficiency goals for their sector and their companies; and
- sector benchmarking.

For details on the background and current activities of CIPEC, see Section 1.2 (page 7).

Industrial Energy Innovators (IEI)

The IEI is a voluntary program to foster individual companies' efforts to improve energy efficiency and take action on climate change. When the president or chief executive officer of a company signs a letter of commitment to implement energy-saving measures in the organization, NRCan registers the company as an Industrial Energy Innovator. As part of its commitment, each participating company develops and implements an energy efficiency improvement target or goal-setting process and action plan, nominates an energy efficiency champion, and tracks and reports the results of its energy efficiency activities annually. NRCan provides registered Innovators with support services such as energy management workshops, seminars on new technologies and operating practices, sector-specific energy efficiency guidebooks, an international technical information network, an employee awareness toolkit and energy management newsletters.

For further information on CIPEC and the Industrial Energy Innovators, contact

Philip B. Jago
Chief, Industrial Energy Efficiency
Office of Energy Efficiency
Natural Resources Canada
580 Booth Street, 18th Floor
Ottawa ON K1A 0E4

Telephone: (613) 995-6839
Fax: (613) 947-4121
E-mail: pjago@nrcan.gc.ca

Apart from the OEE, the CANMET Energy Technology Centre of NRCan also has programs to promote the energy efficiency development. They are outlined in the following.

CANMET Energy Technology Centre (CETC)

The CETC works with industry, trade and professional associations, utilities, universities and other levels of government to develop and deploy leading-edge technologies in the areas of residential, commercial and industrial energy efficiency and alternative, renewable and transportation energy technologies. The CETC provides leadership in its energy-related technology areas through its repayable and cost-shared contract funding programs. Following are two of its funding programs:

- the Emerging Technologies Program (ETP); and
- the Industry Energy and Research Development (IERD) program.

These programs are listed under "Funding Programs" at the following Web site: http://www.nrcan.gc.ca/es/etb/cetc/cetchome.htm.

Emerging Technologies Program (ETP)

The ETP helps industries identify and develop emerging energy-efficient technologies with significant potential to reduce energy consumption, limit emissions of greenhouse gases, improve manufacturing competitiveness and reduce the environmental impact of manufacturing processes. Through alliances with public and private sector partners, including other governments and utility companies, the ETP supports sector studies, technological assessments, field trials of technologies and research and development (R&D) activities. Contributions are repayable either from revenues or from cost savings realized from successful projects. The ETP also helps companies claim the 30 percent capital cost allowance on eligible energy-conserving and renewable-energy equipment.

Sector studies: A sector study identifies established, new and emerging energy technologies specific to particular industry sectors and ranks them for their merit in

- improving productivity;
- improving energy efficiency; and
- reducing the environmental impact of production and energy use.

The ranking produced by a sector study should form the starting point for that sector's R&D activities for the next 20 years. Studies for some of the industrial sectors that are currently available are listed in Appendix C (page 183).

Technology assessments: A technology assessment is a detailed evaluation of a specific R&D project. It describes the potential energy benefits, environmental impacts, markets and implementation economics of the subject technology and identifies the R&D activities and participants needed to bring the subject technology to commercial acceptance. Technology assessment fact sheets that are currently available are listed in Appendix C (page 183).

Follow-on R&D activities: Follow-on R&D activities are the development and testing of products and processes covered by technology assessments, using prototypes or pilot plants.

Technical field trials: Technical field trials are conducted with promising technologies and techniques that have yet to be used or proven in Canada. The results are summarized in fact sheets and distributed to all interested parties. Fact sheets that are currently available are listed in Appendix C (page 183).

For information or to discuss a possible initiative in a particular sector, contact

Norman Benoit
Program Manager
Emerging Technologies Program
CANMET Energy Technology Centre
1 Haanel Drive
Nepean ON K1A 1M1

Telephone: (613) 996-6165
Fax: (613) 995-7868
E-mail: nbenoit@nrcan.gc.ca

Industry Energy & Research Development Program (IERD)

The IERD program supports Canadian companies engaged in energy efficiency R&D. It focuses on promoting the development of products, processes or systems that will increase the efficiency of energy use by industry. IERD support generally takes the form of loans of up to 50 percent of the cost of the project, repayable when the product or process goes on the market. To find out whether a project is eligible for IERD support, to obtain instructions for applying to IERD or for general information, contact

Jacques Guérette
Program Manager
IERD Secretariat
Natural Resources Canada
1 Haanel Drive
Nepean ON K1A 1M1

Telephone: (613) 943-2261
Fax: (613) 995-7868
E-mail: jguerett@nrcan.gc.ca

Provincial and territorial government activities

Following is a list of provincial and territorial government officials responsible for delivering programs to promote energy efficiency at the sector, sub-sector and company levels of the economy.

Where applicable, information about programs or other types of assistance is provided to indicate the type and range of programs currently available. Please contact the following for the latest update.

Please note: Every effort has been made to obtain the most up-to-date contact information possible.

Alberta

Andy Ridge
Senior Analyst, Climate Change Group
Alberta Department of Environment
14th Floor, North Petroleum Plaza
9945 108th Street
Edmonton AB T5K 2G6

Telephone: (403) 422-7862
Fax: (403) 427-2278
E-mail: andy.ridge@gov.ab.ca

Energy efficiency and encouraging sustainable energy use is the key focus of this group, which provides technical and educational assistance and may develop appropriate programs.

British Columbia

Denise Mullen-Dalmer
Director, Electricity Development Branch
Economic Development Division
Ministry of Employment and Investment
4-1810 Blanshard Street
Victoria BC V8W 9N3

Telephone: (250) 952-0264
Fax: (250) 952-0258
E-mail:
denise.mullendalmer@gems1.gov.bc.ca

Currently no industry-oriented assistance programs are available.

Manitoba

Terry E. Silcox
Technical Advisor
Manitoba Conservation
1395 Ellice Avenue, Suite 360
Winnipeg MB R3G 3P2

Telephone: (204) 945-2035
Fax: (204) 945-0586
E-mail: tsilcox@em.gov.mb.ca

Manitoba Conservation maintains a Technical Advisory Service for the industrial, commercial and institutional sector. It provides advice and technical information and disseminates appropriate publications and brochures. No grants or rebates are available through this program. Limited information from the Energy Audit Database is also available.

New Brunswick

Darwin Curtis
Director, Minerals and Energy Division
New Brunswick Natural Resources
  and Energy
P.O. Box 6000
Fredericton NB E3B 5H1

Telephone: (506) 453-3720
Fax: (506) 453-3671
E-mail: dcurtis@gov.nb.ca

Newfoundland and Labrador

Brian Maynard
Assistant Deputy Minister
Department of Mines and Energy
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The Arctic Energy Alliance (AEA) is co-funded by the Resources, Wildlife and Economic Development (RWED) Department. It assists energy users to reduce consumption, expenditures and environmental impacts of energy usage. The AEA delivers an energy management program on behalf of RWED, also aimed at industry. It includes provision of energy assessments, audits and public awareness assistance.

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Among the programs available to industrial users is one for promotion of energy efficiency in Quebec that offers professional and financing help of up to 50 percent for eligible projects that demonstrate energy efficiency in the framework of sustainable development in the province.

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Technical and general information only is available from Saskatchewan Energy and Mines.

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A publication that outlines programs available to industry is available. It includes Yukon infrastructure support policy, loans for resource development and energy management program, including financial contributions, training and energy auditor training, and a large number of other programs of interest to industry.

Associations and utilities

Electrical utilities

The following list of program types indicates the assistance that electrical utilities were providing at the time of writing. To find out what assistance is available in your area, contact your utility; a list of names and addresses appears at the end of this section. The list has been updated, as was the information about assistance programs, where available.

Please note: Every effort has been made to obtain the most up-to-date contact information possible.

Electro-technology programs: Utilities are urging some large industrial customers to adopt new high-performance electro-technologies such as microwaves, variable-speed drives, high-frequency heating and drying and infrared heat treatment. The utilities are promoting these technologies to foster technology innovation by sharing the investment risk with their customers. Some utilities provide loans for initial demonstrations of electro-technologies or for new applications of established technologies.

Energy awareness seminars: Many utilities offer seminars on energy management topics of interest to industry, as well as energy efficiency programs.

Energy audits: Utilities provide walk-through audits of industrial facilities to identify for their customers the points where electrical demand could be reduced. Case studies are sometimes provided.

Interruptible rates: A utility may offer reduced rates for customers who can adapt to a reduced electricity supply at times when the utility's system is at peak load. A variety of rates may be offered, based on the length of time the customer agrees to reduce its demand. Interruptible rates permit industries to reduce demand charges by as much as 30 percent.

Time-of-use rates: Time-of-use rates encourage large industrial customers to shift their demand for electricity away from the utility's daily peak periods. For example, high-demand processes could be changed to the night shift.

Real-time pricing: A utility may allow high-demand customers to cut costs by shifting all or part of their load to periods when the utility's generation cost is relatively low. In a real-time pricing plan, the utility usually quotes prices for every hour of energy use one day in advance.

Industrial energy efficiency award programs: Some utilities have award programs to recognize industries that significantly improve their energy productivity. By promoting energy efficiency awards, utilities raise awareness of energy-efficient equipment, electro-technologies and energy management techniques.

Provincial electrical associations: In many provinces, contractors, equipment suppliers and others in the electrical industry have established trade associations to provide trade-specific advice, guidance, technical support and training.

PowerSmart® Inc.: Available through electrical utilities in British Columbia, Manitoba and Newfoundland, PowerSmart® offers a number of programs and products, as locally applicable. Check the appropriate listings below.

Alberta

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EPCOR started EnVest™ in 1997 as a comprehensive, three-stage energy and water efficiency program, designed specifically for industrial and commercial facilities. It starts with a detailed audit of the facility to identify opportunities to reduce utility cost related to water, natural gas and electricity. The second stage is the implementation of the recommendations of the audit. EnVest™ offers project management services. The final stage of the program is a financing option for the execution of water and energy cost reduction projects.

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ATCO Energy Sense has these programs available:

- energy efficiency publications, including Energy Sense guides on numerous energy-efficient technologies such as lighting, motors, compressors, etc.;
- Energy Efficiency Assessment Program, a no-cost service that includes a walk-through auditing service, written report with recommendations and a provision of specific tools to help the customer to determine equipment operating costs and savings potential;
- training services; and
- tools and equipment, such as light meters and load loggers, available on loan to customers who wish to perform some tests themselves.

British Columbia

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PowerSmart can help businesses save energy and money. Following are highlights of the PowerSmart resources available.

Investigate energy efficiency opportunities:

- Resources include detailed on-line technical guides on energy-efficient technologies, workshops and training sessions on energy-efficient practices and "e.Catalogue" – a single on-line source for finding energy-efficient products.

Identify energy savings:

- Programs and tools are available to provide businesses with a profile of their energy use and recommendations for energy-saving opportunities.

Implement energy-saving projects:

- PowerSmart Alliance – connects customers with qualified contractors and engineers who can help them select, install and maintain their facility's energy-related systems.
- PowerSmart Partner Program – for qualified customers who commit to reduce their energy consumption. Provides access to matching funding and educational resources to help them implement energy-saving projects.

For more information on current PowerSmart programs and initiatives, call (614) 453-6400 (Lower Mainland); 1 866 453-6400 (elsewhere); or visit the Web site at http://www.bchydro.com/business.

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Manitoba Hydro offers a free information service through the PowerSmart® Program. No rebates are available.

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Current energy efficiency information is maintained at http://www.energy-efficiency.com

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Ontario Hydro Energy Service Package

Ontario Hydro Energy is committed to developing business relationships that increase competitiveness and maximize the value received from electricity, natural gas and water services. Its primary focus is to deliver comprehensive utility management programs to multi-residential, commercial and industrial markets throughout Ontario and Canada. Services are strategically designed to deliver utility cost savings, reduce building operating costs and add value to clientele portfolios where applicable. Its services provide all up-front analysis and engineering, installation, project financing, post-project monitoring and verification at exceptional levels.

PowerSelect
This service performs on-site power quality analysis and recommends power protection solutions. PowerSelect will supply required equipment, including UPSs, emergency back-up generation, power factor correction, surge suppression, power conditioners and voltage regulators.

MeterSelect
MeterSelect offers services to help customers identify and manage their real-time energy. New, intelligent meters can provide a single-point data collection for multiple measurement points (i.e. electricity, gas and water consumption; temperature). MeterSelect assesses the need, recommends the metering requirements and manages the procurement and installation of metering solutions. MeterSelect also offers an independent monitoring and verification service for validating procurement and performance contracts.

Custom Solutions
This program is designed to ensure that customers receive optimal value in their use of energy through engineering solutions to reduce operating costs and facilitate infrastructure renewal. This may involve implementation of improvements to HVAC, lighting, controls, the building envelope and water-consuming systems. Custom Solutions provides audits, feasibility studies, equipment procurement and installation to ensure that the physical plant is operating efficiently. Financing options are also available, including performance guarantees and feasibility studies to verify calculations of energy savings.

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Electro-technology implementation support, which involves technical assistance to identify and select the most efficient electrical technology to meet a customer-identified need. The service is free of charge. Financial assistance may be available.

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Electromagnetic compatibility study service helps a customer to identify the source of electrical signal pollution in its facility and suggest the solution to it. A charge may apply for the service.

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Petroleum industry

The Canadian petroleum industry helps its industrial customers improve their fuel efficiency. Many suppliers provide technical expertise and evaluation services. Ask a sales representative for information on energy-saving programs and technologies.

Natural gas utilities

Natural gas utilities offer industrial customers a variety of programs to help them reduce energy costs and improve operating efficiencies. Working individually and through the Canadian Gas Research Institute, natural gas utilities also distribute many publications on energy efficiency. To find out what assistance is available in a particular area, contact the utility; a list of names and addresses appears at the end of this section. The list has been updated, as has the information about assistance programs, where available.

Technical assistance: Many utilities offer their industrial customers advice on applying new technologies. They may also support feasibility studies, small-scale cogeneration projects, energy audits and energy-use monitoring projects.

Training: Some utilities provide courses themselves or in conjunction with other organizations.

Interruptible and time-of-use rates: By offering lower rates to industries that accept a lower volume gas supply during their utilities' peak demand periods or by informing industrial customers of impending variations in energy prices, these pricing-plan programs encourage high-demand customers to shift energy consumption to off-peak times and seasons.

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No energy efficiency programs are currently available through BC Gas.

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Two forms of assistance from Gaz Métropolitain to industry are available:

- technical assistance to identify optimum gas technology for a specific application; and
- financial programs to improve the project profitability when converting to natural gas.

Saskatchewan

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SaskEnergy/TransGas carries out studies to determine the probable savings to industry when converting process equipment from electricity to natural gas, and other opportunities for reduction of power consumption. As well, a provincial Building Energy Management Program is available to industrial customers and is delivered by the Saskatchewan Research Council in Saskatoon.

Other sources of assistance

Technical ideas and assistance with the development of energy efficiency projects, testing and other projects can often be obtained from a research institute that serves the particular industrial sector. As an example, PAPRICAN (Pulp and Paper Research Institute of Canada) could help with information about electrical impulse drying of wood. This is yet another option that should be considered in searching for a specific solution to a problem.

The Internet is an excellent source of information on energy efficiency. Numerous Web sites are available. The OEE carries a list of links to international sources of information accessible from its home page (http://oee.nrcan.gc.ca). Among them, the site for the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) at http://caddet-ee.org is especially worthwhile investigating. Canada is a participant in a multinational group that collaborates in exchanging energy-related information through CADDET, which maintains the site. As a service to readers, Part 2 of this Guide includes references to various up-to-date energy-efficient technologies, developed by CADDET member countries. Various reports, analyses and technical brochures can be obtained in Canada through the OEE.

part 2

Technical guide to energy efficiency planning and management

2.1 Managing energy resources and costs

The first part of this Guide dealt with general principles of establishing and running an effective energy management system in a facility – focusing mainly on organizational and people issues. This section looks at how, within that management system, the cost and the utilization of energy resources can be systematically and methodically controlled.

2.1.1 Energy market restructuring in Canada

Electricity

In Canada, several provincially owned and regulated electric utilities are being restructured to meet the challenges of a more competitive, increasingly integrated North American electricity market. The Government of Canada supports continued efforts of provinces to liberalize trade and establish competition in electricity markets.

Given the extensive role of the provinces and territories in the electricity sector, the first decisions in restructuring the industry *must* be taken by them. The urgency of addressing restructuring issues varies across provinces, and progress varies among provinces as a result of regional cost, supply and social factors. Alberta, British Columbia, Manitoba and Quebec allow wholesale access to their transmission systems. Alberta implemented retail access in January 2001. Ontario has opened the wholesale and retail markets.

Restructuring requires a complex transition from a regulated utility to competitive markets. In some jurisdictions, the transition to competitive markets has been very difficult. However, there are other models of restructuring that appear to be more successful and have brought competition to the market, enhanced energy efficiency and resulted in savings to consumers. Provinces will continue to watch closely as competitive markets are introduced in other markets.

Natural gas

Prior to 1985, federal and provincial regulators were involved in establishing natural gas prices and in deciding how much gas could be exported. The change to market-determined pricing of natural gas created greater competition, especially in the 1990s.

The idea behind such deregulation is simple. If competition increases at the retail level, residential and commercial energy consumers will benefit through competitive prices and services and greater choice. This approach illustrates a major trend in North America: there is more competition for the energy consumer's dollar as increasingly sophisticated companies begin marketing energy (not just natural gas) to consumers.

Producing companies now sell to many different kinds of buyers. These include industrial customers, independent marketers, local distribution companies, marketing companies such as affiliates of pipeline companies and other sales organizations. Further, since 1990, gas futures contracts offer buyers and sellers the means to manage price risk.

Purchasing energy – playing the spot market

Since the energy market is inherently volatile and volatility is the bane of the industry, companies must look for ways of reducing their risk. It means that energy efficiency and demand side management will be increasingly valuable tools for business to manage costs. Individual customers will have to become more savvy in the ways that they purchase and use energy. They will have to pay closer attention to energy market conditions so that they can budget for energy and spend the money wisely. There are parallels to the stock market, and there are also implications for energy efficiency improvements. The reader should be aware that some large industrial users of energy in Canada already find it profitable to assign resources to follow the energy market constantly and to take advantage of the spot prices in making their purchasing decisions. Software packages are available for this purpose. As elsewhere in the Guide, specific service providers or product manufacturers are not mentioned by name.

This subject has been noted for a reason: to maximize the use of a finite resource – the company's energy budget. If smart energy purchases under these new, fluctuating market conditions can save money, there will be more to spend on energy efficiency improvements, and vice versa. Conversely, as more companies may consider combined heat and power generation (CHP, or cogeneration) in the future, the energy market would also interest them from a revenue point of view.

2.1.2 *Monitoring and targeting*

Monitoring and targeting (M&T) is a very important tool for practical, hands-on and goals-oriented energy management. It was made possible by developments in computer technology and in instrumentation, measuring and monitoring equipment. The use of the method is relatively new to Canada. It uses a disciplined and structured approach, which ensures that energy resources are provided and used as efficiently as possible. It is applicable to other utilities, such as water and gas as well as to a range of process raw materials and products-in-process streams. The installation of an M&T system can bring a fast payback – usually within the first year of operations.

The fundamental principle of M&T is that energy and other utilities are direct and controllable costs that should be monitored and controlled in the same way as other direct, production-related costs such as labour and raw materials, parts and supplies. This principle is expressed as a board-level policy in companies, which embraced M&T in order to derive benefits from it.

Control implies responsibility and accountability. The M&T process begins with dividing a plant into energy-accountable centres (EACs), some of which convert energy and others that use it. For practical reasons, EACs should correspond to existing management accounting centres and should not straddle different managers' jurisdictions. Within each EAC, energy consumption (i.e. electricity, gas, steam) is monitored. For additional control, energy may be monitored in specific areas within an EAC. The plant controller should also be involved since this person will want to know how these controllable costs are managed.

Managers are responsible and accountable for energy use. The review of usage of energy (and other utilities) against the standards and budgets becomes a constant agenda item on monthly operational review meetings of the management team. As well, energy usage (or savings) may be included in the managers' personal key performance objectives and evaluations. As a result, energy matters receive the same level of attention as production and financial performance indicators.

The cost of implementing an M&T system will depend on the extent of installed metering, the coverage desired and the methods used for recording and analysing energy use. The scope can be adjusted in line with the savings expected. Measuring requires installation of meters at key points in the plant, especially at equipment with large energy consumption. The M&T system should be optimally developed hand-in-hand with a site-wide energy management computerized system that encompasses condition monitoring and automation. However, experience proves that the cost of installing these meters and the associated monitoring equipment and computers will soon be offset by the energy efficiency gains from the M&T program. For example, one Canadian plant spent $200,000 on the system and realized savings of $1.5 million in the first year alone.

For each item monitored, such as boiler efficiency, a suitable index is needed against which to assess performance. For each index, a performance standard needs to be derived from historical data that take into account factors that can significantly affect efficiency. If historical data are not available, for example because of the prior lack of instrumentation, six or eight months of data gathering must precede the establishment of a standard. Again, the managers involved must agree upon the derived standards.

Targets are derived, just as are standards. They represent improvements in energy use efficiency. To ensure that the process will work, the managers having their consumption targeted must agree that the targets are realistic. The gradual but progressive resetting of targets in time toward better energy efficiency levels is the start to continual improvement.

Several firms are marketing M&T software and hardware packages and are available to assist with implementation. Further information may be obtained from the OEE's Web site at http://oee.nrcan.gc.ca.

2.2 Process insulation

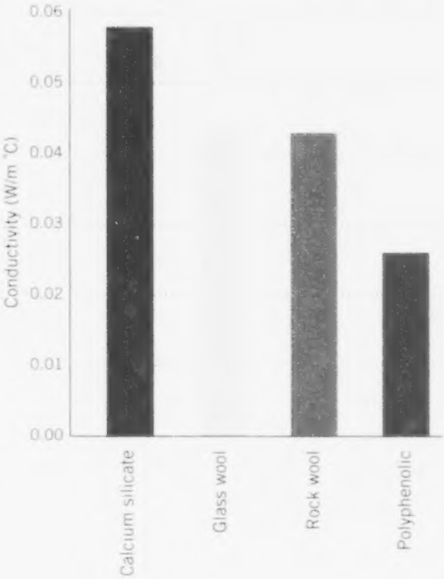
Thermal insulation on process equipment and piping has several functions:

- preventing losses and gains of heat;
- maintaining consistent process temperatures;
- protecting employees from burns and frostbite;
- preventing condensation from forming on cold equipment surfaces; and
- maintaining comfortable working environments around hot or cold process equipment.

The benefits of installing or increasing insulation on process equipment and piping are particularly attractive if fuel costs have increased since the equipment was designed and installed. Thermal insulation deteriorates over time, and re-evaluation of long-established systems may show that the insulation is inadequate or damaged. See Figure 2.1 for information on thermal conductivity.

FIGURE 2.1

Thermal conductivity



Economic thickness of insulation

The key step in an analysis of insulation involves determining the most economic thickness to install, which means the thickness of insulation that saves the most energy per dollar in installation cost. For more information on economic thickness, refer to the technical manual *Process Insulation* (Cat. No. M91-6/1E); see page vi of the preface for ordering instructions.

Keep moisture out

Insulation that depends on air-filled voids to function effectively must be kept dry. Exposure to moisture, particularly in the case of loose-fibre or open-cell foam insulation types, causes the displacement of insulating air by heat-conducting water or ice. Protecting insulation from moisture/water ingress is just as important as selecting the most effective type of insulation and installing an economic thickness. The practical requirement, then, is to make waterproofing an integral part of any insulating job.

Waterlogged insulation transfers heat ***15–20 times faster*** than dry insulation!

- Install adequate, leak-proof vapour barriers on the interior (warm) side of walls, ceilings or floors.
- Weatherproof exterior walls by cladding or other treatment that prevents water infiltration.
- Maintain the integrity of water-impervious roof membrane by regular inspection and maintenance.
- Cover insulated pipes with suitable cladding (whether for indoor or outdoor applications) with sealed joints, and maintain its integrity by inspection and prompt repair of damaged sections.

- For high-temperature applications, choose a vapour-permeable covering that will allow moisture to pass outward.

The economic thickness of insulation is the thickness that provides the highest insulation for the lowest cost. One way of improving cost savings through insulation is to upgrade to the levels of insulation shown in the recommended thickness tables (see the manual *Process Insulation*, Cat. No. M91-6/1E), which can be used for guidelines.

Environmental considerations

Whether we insulate to prevent heat loss or heat gain, we help to reduce greenhouse gas emissions. Except for nuclear power and hydro-electricity, energy is produced by burning fossil fuels. Insulating against heat loss (e.g. steam pipes and pipes carrying hot liquids) reduces the amount of fuel needed to fire the boilers that produce the heat – and the emissions. Insulating against heat gain (e.g. refrigerated spaces or pipes carrying cold fluids) reduces the amount of electrical energy needed to operate the chillers that provide the cooling. Thus, wherever electricity is used, reducing consumption leads to a reduction of emissions from thermo-electricity-generating stations. See Section 1.1, "Climate change" (page 1) for a discussion of pollutant reductions due to energy efficiency improvements and instructions for calculating them.

Material choice based on

- Halocarbons-free
- Flammability
- Performance

More detailed information

Process Insulation (Cat. No. M91-6/1E), published by NRCan, contains information that can be complemented by the use of computer-assisted design software, some of which is listed in NRCan's *Energy Audit Software Directory* (Cat. No. M27-01-570E). Note also that the materials specifications date from the mid-1980s, when the manual was first issued.

Tip

Consider an NPS 6 steel pipe operating at 121°C, in ambient conditions of 21.1°C. Left uninsulated, it will lose 700 Wh per metre of length per hour. With 76 mm of mineral fibre insulation, the loss would drop to 37 Wh/m/h, and the temperature of the outer surface would be 23°C.

Energy management opportunities

It bears repeating: "Energy management opportunities" (EMOs) is a term that represents the ways that energy can be used wisely to save money.
Some of the EMOs in this category can be outlined as follows:

Housekeeping EMOs

- Repair damaged insulation.
- Repair damaged coverings and finishes.
- Maintain safety requirements.

Low-cost EMOs

- Insulate uninsulated pipes.
- Insulate uninsulated vessels.
- Add insulation to reach recommended thickness.

Retrofit EMOs

- Upgrade existing insulation levels.
- Review economic thickness requirements.
- Insulate major uninsulated equipment/process areas.
- Limited budget upgrade.

> Ice-filled insulation transfers heat ***50 times faster*** than dry insulation!

Work in this category usually requires detailed analysis by specialists.

Process insulation evaluation worksheet

Insulation

Locate and note the condition of insulation on pipes, equipment and containers.

Are pipes and equipment insulated?

☐ Yes Check condition of insulation periodically.

☐ No Arrange to insulate with economic thickness.

Use the manual *Process Insulation* (Cat. No. M91-6/IE) to estimate savings.

Done by: ____________________ Date: ____________________

Is the insulation dry?

☐ Yes Check condition of insulation periodically.

☐ No Locate source of moisture; in particular, establish whether the pipe or equipment is leaking.

Replace wet insulation; it has very little insulating value.

Done by: ____________________ Date: ____________________

Is the insulation thick enough? (Insulation of hot surfaces should be cool to the touch.)

☐ Yes No action required.

☐ No Consider adding more insulation; ask the manufacturer or an insulation contractor whether increasing the amount would be economical.

Done by: ____________________ Date: ____________________

Is the insulation protected against mechanical damage by suitable cladding/covers?

☐ Yes Check condition of insulation covers/cladding periodically.

☐ No Repair/install appropriate cladding/covers as soon as possible.

Check underlying equipment for moisture damage.

Replace damaged insulation.

Done by: ____________________ Date: ____________________

Has the compressive strength of the insulation material been considered when assessing mechanical protection?

☐ Yes Check condition of insulation periodically.

☐ No Choose appropriate type of jacketing/cladding.

In places prone to mechanical damage, consider using more resilient insulation.

Consider placing outside mechanical protection (barriers, bulwarks, shields, bridges, etc.) to minimize chances of damage.

Done by: ____________________ Date: ____________________

On insulated outdoor pipes, equipment and vessels, are the vapour barrier and weatherproof jackets intact?

☐ Yes Check condition of insulation periodically.

☐ No Repair as soon as possible.

Check underlying equipment for moisture damage.

Replace damaged/wet insulation.

Done by: ____________________ Date: ____________________

Are the insulation accessories that secure, fasten, stiffen, seal or caulk the insulation and its protective cover or finish compatible with each other and with the environment?

☐ Yes Check condition of insulation periodically.

☐ No Replace non-compatible parts to ensure system's integrity, prevent corrosion, cracking, etc.

Use proper installation and insulation methods for hangers or supports to minimize energy losses.

Pay particular attention to proper insulation of valves, flanges, elbows, etc.

Done by: ____________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.3 Lighting systems

Lighting technology has produced many recent developments in energy-use reduction; many industries have upgraded their lighting systems, and lighting manufacturers have brought more efficient products onto the market. However, in most facilities, the lighting system still presents significant opportunities to reduce electricity costs.

The first step in reducing electricity costs related to lighting is to survey your facility to find out whether the lighting equipment in each area is appropriate for the work performed there and whether it is the most energy-efficient type available for the task.

The *Energy Efficiency Act*

In 1996, new regulations under the *Energy Efficiency Act* required that lighting systems in major buildings, including industrial buildings, be evaluated. The Act sets minimum requirements for lamp efficacy (expressed in lumens per watt) and for lighting quality (measured against a colour-rendering index). The goal of the new regulations is to reduce national annual energy consumption by 134 petajoules by 2020. Already, several inefficient lighting products have been removed from the Canadian market.

Your facility survey should also determine whether your lighting system conforms to the *Energy Efficiency Regulations*. Help with interpreting and complying with the requirements is available from lighting design consultants, electricity suppliers and manufacturers of lighting products.

Lighting surveys often reveal one or more of the following energy management opportunities:

- **Lights left on in unoccupied areas**: Even the most efficient lights waste energy when they are left on unnecessarily. The best way to ensure that lights are turned off when they are not needed is to develop the occupants' sense of responsibility so that they take care of turning off unneeded lights. You may also consider installing timers, photocells and occupancy sensors or integrating the lighting system into an energy management control system. Lights (and other powered equipment, such as fans) left on unnecessarily in refrigerated areas add substantially to the refrigeration load. The same applies to air-conditioning systems.
- **Dirty lamps, lenses and light-reflecting surfaces**: Dust and grease deposits on lighting fixtures can reduce the light that reaches the target area by as much as 30 percent. Lighting fixtures should be cleaned at least once every two years, and more often when they are installed in greasy, dusty or smoky locations and when they are part of a heating, ventilating and air-conditioning (HVAC) system.

Tip

Bulb efficiency, %:

Incandescent = 100

Fluorescent = 300

Metal halides = 400–600

HP sodium = 450–700

Tip

Buying the most efficient lighting system available today does not have to cost more than using standard fixtures and standard design. In fact, the project's first cost may be reduced by using the most efficient available fixtures and designs. To achieve that, three key concepts should be noted:

- use only recommended lighting levels;
- use parabolic fixtures with T-lamps and electronic ballasts; and
- take advantage of lower A/C size and costs.

- **Overlit areas**: In areas with more lighting than the activities require, remove some lights or install dimming systems. Lighting requirements vary widely within a building, and a reduction in general area lighting combined with an increase in task or workstation lighting often increases the occupants' comfort while decreasing electricity costs. When delamping areas that are lit with fluorescent and high-intensity discharge fixtures, ensure that the ballasts are disconnected; they consume electricity even when the bulb is removed. Dimming systems are useful for areas where several types of activity take place. For example, plant production areas can be fully lit during production periods and dimmed when cleaning and security staff are on duty.
- **Obsolete lighting equipment**: Updating your lighting system with more energy-efficient equipment is usually cost-effective. Retrofitting should be considered to improve the overall energy efficiency of the facility as well as to bring the lighting system into compliance with the *Energy Efficiency Regulations*.

Consider increasing the use of daylighting, where feasible. Cutting energy use for lighting reduces not only the cost of electricity but also the load on your air-conditioning system.

Environmental considerations

Measures taken to reduce electricity consumption by lighting systems help reduce emissions from thermo-electricity-generating stations. See Section 1.1, "Climate change" (page 1), for a discussion of emissions reductions and instructions for calculating them.

Need more information about lighting issues? Visit the Web site of the International Association for Energy-Efficient Lighting (http://www.iaeel.org) or the ENERGY STAR® Web site (http://www.energystar.gov/products).

Tip

Turn off

- incandescent lights when they are not needed;
- fluorescent lights when they will remain off for at least 15 minutes; and
- high-intensity discharge lights when they will remain off for at least an hour.

Tip

Establish a regular cleaning program for your skylights and windows.

Lighting systems evaluation worksheet

Operation

Walk through the facility after hours, noting whether lights are off in unoccupied areas.

Are lights off in unoccupied areas?

☐ Yes Check periodically.

☐ No Train staff to turn lights off when they leave for the day.

Ask security or cleaning staff to ensure that lights are turned off.

Consider installing timers or occupancy sensors that turn lights off automatically.

Consider installing a lighting management system for the facility.

Consider installing motion-detector switches for the outside yard and building perimeter lighting.

Done by: ______________________ Date: ______________________

Are light fixtures clean?

☐ Yes Check periodically to maintain standard.

☐ No Wash lamps, lenses and reflecting surfaces to remove accumulated dirt and grease.

Done by: ______________________ Date: ______________________

Survey the facility with a light meter and compare readings with standard lighting requirements for tasks.

Are light levels appropriate for the work performed in each area?

☐ Yes Check periodically to maintain standard.

☐ No If light levels are too high, consider removing lamps or retrofitting with high-efficiency low-wattage lamps.

If light levels are too low, consider installing task lighting; if task lights are not feasible, consult a lighting expert.

Done by: ______________________ Date: ______________________

Application of lighting types

Note the various types of lights and fixtures used throughout the facility.

Are any areas lit with incandescent lights?

☐ Yes Consider replacing lights with *Energy Efficiency Act* (EEA)-compliant high-efficiency lamps, such as fluorescent or high-intensity discharge lamps, whichever is more appropriate.

Consult a lighting expert.

☐ No No action required.

Done by: ______________________ Date: ______________________

Are large, high interior spaces lit with inefficient fluorescent lights?

☐ Yes Consider replacing fluorescent lights with EEA-compliant high-intensity discharge lighting, such as metal halide or high-pressure sodium fixtures.

☐ No No action required.

Done by: ______________________ Date: ______________________

Are large areas lit with mercury vapour lights?

☐ Yes If the colour-rendering qualities of the mercury vapour lights are not required, consider installing EEA-compliant metal halide or high-pressure sodium lights, which are more energy efficient.

☐ No No action required.

Done by: ______________________ Date: ______________________

Do all light fixtures in the facility meet EEA requirements?

☐ Yes No action required.

☐ No Consult a lighting expert who can recommend suitable equipment that meets the EEA requirements.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.4 Electrical systems

Electricity is the most widely used form of energy in most facilities, yet electrical systems are among the least understood of all plant systems.

In most industrial operations, four kinds of opportunities for reducing electrical costs are available:

- reduce peak demand, i.e. the maximum power (in kW/kVA), required by the facility;
- reduce the total energy (measured in kWh) consumed in the facility;
- improve the power factor of the facility; and
- shift energy consumption to a time when energy costs are lower.

Understanding electrical billings

Understanding the billing rate structure used by your utility is an important first step in taking control of electrical costs. Most industrial and commercial facilities are billed for electricity according to a general-service rate schedule in which the customer pays for the peak power demand (kW/kVA) and energy consumption (kWh). Most general-service rate structures also impose financial penalties on plants that have a low power factor.

Time-of-use rates

Many utilities have time-of-use or time-differentiated rates for customers whose peak demand exceeds 5000 kW. These pricing schemes offer very low rates to customers who can shift high-demand operations away from the times of day when the utility receives its peak demand for energy. The utility benefits from a more consistent daily load pattern, and the customer pays less.

Time-shifting consumption and real-time pricing

Some utilities now offer their major customers real-time pricing, a scheme in which, each day, the utility gives the customer the rates proposed for each hour of the following day. Because of fluctuations in demand, electricity rates vary widely through the day, and the customer that can schedule its high-consumption activities to low-cost times of day can realize substantial savings.

Software is available for estimating energy costs in a variety of situations. These estimates usually require complex analyses to arrive at the best mode of use, depending on operational restraints imposed by factors such as equipment requirements. Some software will even estimate control capabilities based on the consumption pattern decided after analysis. For information about available software and analysis tools, consult your electrical utility.

Energy management opportunities

Look at the electrical load analysis and, using some of the ideas shown in the following, develop a systematic management approach to electrical power usage. Consider using one of the predictive, "smart" demand side management (DSM) programs that are available on the market. DSM refers to installing efficiency devices to lower or manage the peak electric load or demand. (Note: other DSM programs are also available, e.g. for natural gas usage.) A network of on-line electrical metering enables real-time data to be collected from the meters and the computerized energy management system to predict and control the electrical demand. When the demand approaches preset targets, non-essential operations are cut off and held back to shave the peak demand (see the following).

Remember also that the effort must be broad-based and have the support of the operators. An awareness campaign should be the start. Are the employees aware of the energy and utilities cost and of the level of those expenditures in the plant? Is there an effective communications system in place to share the results of the conservation efforts with everybody?

Peak demand

The maximum demand on electric power that occurs in a timed period (e.g. 30 minutes).

Reducing peak demand

A facility's peak demand is the sum of the power (kW/kVA) required to run all the electrical equipment currently in operation. Thus, the demand peak increases and decreases as equipment is turned on and off and as the load goes up and down. Peak demand charges are based on the highest peak occurring in the billing period, even if that peak lasts for only one or two hours. Since demand peaks are usually predictable, they can be lowered by:

- shedding loads – shutting off non-essential equipment during the peak period (see Figure 2.2 on page 74);
- shifting loads – re-scheduling operations so that some activities take place during off-peak times of the day (see Figure 2.3 on page 74); and
- improving processes to reduce electrical power requirements.

If, after the implementation of all peak-reducing measures, the peak demand still continues to be unacceptably high, consider installing on-site, engine-driven generators to kick in and help shave the peak load.

Capacity charge (kVA)

A charge intended as payment for the cost of providing the service to the site; it represents the maximum possible demand from the supply system.

Reducing energy consumption

Reducing energy consumption is the simplest part of an electricity cost-reduction plan. First, implement all the usual cost-saving methods, such as the following:

- turning off unnecessary lights and retrofitting lighting systems with appropriate energy-efficient fixtures.

Is there a procedure in place to shut off production and auxiliary equipment when not in use? Is it implemented?

FIGURE 2.2
Load shedding

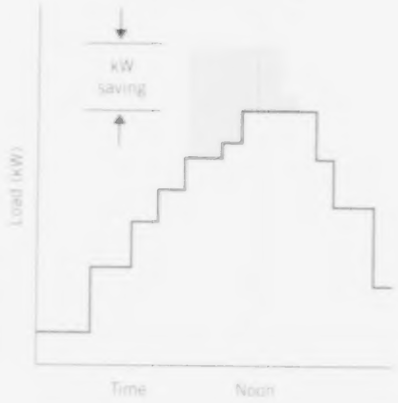
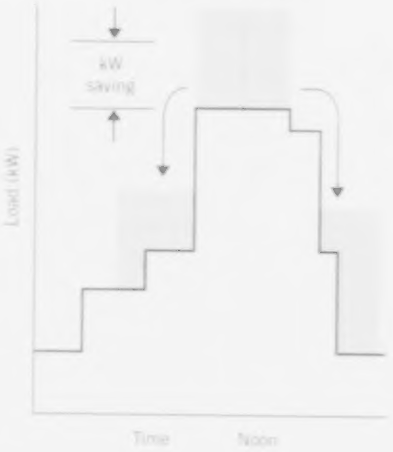


FIGURE 2.3
Load shifting



- shutting down unneeded equipment;
- replacing drives between motor and driven equipment with more energy-efficient variable speed drives (VSDs), investigating the use of hydraulic drives and converting motors to soft-start technology;
- replacing driven equipment with more energy-efficient equipment; and
- replacing old electric motors with new, high-efficiency motors.

Then, look at processes and examine the power usage in various sub-systems (e.g. HVAC, refrigeration, conveying and material handling and compressed air, as detailed in the subsequent chapters in this Guide) so as to reduce electricity consumption.

Installing a power monitoring system, such as one automotive manufacturer did in Canada, coupled with monitoring and targeting methodology of managing electricity consumption, can in itself lead to a drop in electrical energy use (in this particular case, 5.6 percent, worth more than $1 million annually).

Another company tracked and trended power consumption based on production and non-production days. This revealed that large amounts of energy were wasted on weekends. Shutdown sheets were then developed for all plant areas to enforce and document that equipment shutdowns were taking place.

Improving the power factor

The power factor (PF) of an industrial facility is calculated as a ratio of kW (resistive power) divided by kVA (resistive plus reactive power). Remember that the resistive component of the electrical power does the useful work. A low PF is normally caused by inductive loads used by equipment such as transformers, lighting ballasts and induction motors, particularly under-loaded motors. Electrical utility companies penalize customers whose PF is less than 90 percent.

It is in the interest of the facility to maintain a high PF so that the capacity charge (kVA) by the utility does not exceed the established value.

The most common way to improve the PF is to add capacitors to the electrical system. Capacitors are normally installed in one of three configurations:

- as a bank at a main switchboard or central distribution location;
- in smaller groups at a motor control centre; or
- individually, on large power users.

Multiple-capacitor installations usually include a controller that monitors the plant PF and switches capacitors into the circuit as needed to keep the PF high.

However, one large company in Canada replaced all power capacitors in four of their plants with new, microprocessor-based LRC tuning circuits, sized for each specific plant and power load, for its power distribution system. Improved PF correction resulted in energy savings of 9 to 12 percent. Adding a device for intermittent supply failure protection helped to eliminate most of the downtime due to power failures and helped to shorten the payback by 73 percent.

A paper mill installed unity PF multi-motor drives that solved the problem of maintaining a suitable PF over a range of speeds that multiple-motor VSDs could not maintain.

Power factor

The ratio of power passing through a circuit to the product of voltage and current. Electric utilities charge customers a penalty if the PF is lower than a value specified (e.g. 0.9) because difficulties arise in supply and distribution systems when the PF is significantly lower than unity.

Tip

Newly developed adaptive voltage-amps-reactive (VAR) compensator (AVC) can instantly detect changes in reactive demand and insert exactly the right amount of capacitance to restore the PF to unity within one cycle. The PF and equipment life are improved. (See the CANMET publications list – Appendix C.)

Electrical systems evaluation worksheet

Demand

Develop an electrical load profile of the facility. This information may be available from the electrical utility. If it is not, you may have to install electronic recording ammeters and collect data for several months. Analyse the load profiles to determine how the operation of plant equipment affects the profile.

Can equipment use be rescheduled to off-peak hours?

☐ Yes Reschedule operations.

☐ No No action required.

Done by: ______________________ Date: ______________________

Can any of your equipment be shut down during peak-load periods?

☐ Yes If the equipment is manually operated, have the operator shut it down according to a peak-load schedule.

If the equipment is automatic, set the controls accordingly or install a programmed timer.

☐ No No action required.

Done by: ______________________ Date: ______________________

Can any of your equipment be downsized to use less electricity?

☐ Yes Upgrade equipment at the first opportunity; this will also reduce consumption of electrical energy.

☐ No No action required.

Done by: ______________________ Date: ______________________

Consumption

Examine all electrical systems, including lighting, with a view to retrofits or operational modifications that will reduce electrical consumption.

Can equipment be shut off when not in use without disturbing the process?

☐ Yes Inform operators that the equipment must be shut off when not in use.

Consider using timers, photocells or occupancy sensors to ensure that equipment is shut off when feasible.

☐ No No action required.

Done by: ______________________ Date: ______________________

Can equipment be fitted with energy-efficient motors economically?

☐ Yes Replace the motors with energy-efficient units at the first opportunity.

☐ No Examine the possibility of replacing worn-out motors with energy-efficient motors.

Done by: ____________________ Date: ____________________

Can existing lighting be economically replaced with energy-efficient lighting?

☐ Yes Replace the lighting with energy-efficient fixtures and bulbs at the first opportunity.

☐ No No action required.

Done by: ____________________ Date: ____________________

Examine the drive system and driven equipment to find out whether their efficiency can be improved.

Can lower-efficiency drives and mechanical equipment be retrofitted?

☐ Yes Replace the items that are feasible for retrofitting at the first opportunity.

☐ No Examine the possibility of replacing old drives and mechanical equipment.

Done by: ____________________ Date: ____________________

Power factor

Is the power factor at or above 90 percent (0.9)?

☐ Yes Check periodically to maintain standard.

☐ No Consider installing capacitors to increase the power factor; this usually requires a study and design by an electrical engineer.

Done by: ____________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.5 Boiler plant systems

In many industrial facilities, the boiler plant system is the largest fuel user.

A boiler plant program of energy management should begin with an assessment of current boiler efficiencies. Boiler performance monitoring should then be done regularly to gauge the effect of established energy-saving measures and to set improvement targets.

The simplest way to calculate fuel-to-steam efficiency is the direct method of calculation, using steam generation and fuel consumption data from operating logs.

Direct method for calculating boiler efficiency

- Measure steam flow (in kg) over a set period (e.g. one hour). Use steam integrator readings if available.
- Measure the flow of fuel over the same period, using the gas or oil integrator.
- Convert both steam and fuel flow to identical energy unit (e.g. MJ or kJ).
- Calculate the efficiency using the following equation:
  Efficiency = [steam energy / fuel energy] × 100.

The objective of improving boiler efficiency is to reduce heat losses from the boiler system. Heat losses occur in many forms, such as

- flue gas;
- fouled heat-exchange surfaces;
- hot blowdown water; and
- hot condensate.

Heat lost in flue gas

Excess air

Combustion air is the amount theoretically needed to achieve complete combustion of a given fuel. It is fixed by the oxygen content required to convert all of the carbon and hydrogen in fuel to carbon dioxide and water. Air supplied to the boiler over this theoretical amount is called excess air. In practice, some excess air is always required to ensure complete combustion, but most burners operate with more excess air than they need. Hence, it must be controlled.

Excess air reduces boiler efficiency by absorbing heat that would otherwise be transferred to the boiler water and carrying it up the stack. Excess air can be measured with a flue gas analyser. If the flue gas contains too much excess air, a qualified burner technician should adjust the burner and combustion air dampers to reduce excess air levels over the boiler operating range. The boiler should operate in the "zone of maximum combustion efficiency" (see Figure 2.4, page 80).

Remember also that along with controlling the excess combustion air in the burner, it is just as important to guard against infiltration (ingress) of unwanted air into the boiler combustion cavity or the flue system through cover leaks, observation ports, faulty gaskets and other openings.

Deploying of modern combustion technology, including electronic control, oxygen regulations, flue gas analysers and economizers will bring significant overall energy savings.

Tip

The amount of heat rejected by flue gases can be calculated from measurements taken of flue gas temperature and oxygen or carbon dioxide content.

This is the most important control parameter of boiler operations.

Heat-recovery methods

Heat loss in flue gas can be substantially reduced by equipment that diverts the thermal energy in flue gases to other parts of the boiler plant. For example, heat exchangers called economizers transfer heat from flue gas to boiler feedwater, and combustion-air preheaters use the energy in hot flue gases to heat combustion air.

A particularly energy-efficient heat recovery option is the direct-contact flue gas condensing unit, which sprays water through the flue gas stream and passes the heated spray water through a heat exchanger to transfer the heat to boiler make-up water or other plant processes. Flue gas condensers recover the latent heat of vaporization and much of the sensible heat from water vapour in the flue gas, and can reduce the flue gas temperature to 38°C. An incidental advantage of direct-contact flue gas condensing is that it removes particles and acid gases (such as SO_2) from exhaust.

A recently designed system is working on the condensing heat recovery and heat exchange principles; it has, additionally, produced superior air pollution control results. Recovery of 80 to 90 percent of heat in the flue gas previously exhausted to the atmosphere is possible. It is reported that the system can reduce fuel consumption by the facility by up to 50 percent.

Another option is to add a heat pump to convert the low-temperature heat into high-temperature heat for other uses in the plant, thus further increasing boiler efficiency.

Other boiler installations deploy heat-reclaim burners to preheat the combustion air. The burners that contain compact beds of heat-storing material cycle rapidly to allow short-time heat storage and reclamation. The combustion air is preheated to within 85 to 95 percent of the flue gas temperature.

All boilers would benefit from adding an economizer, air heater or flue gas condenser; however, a comparative analysis of the options is needed to determine which would be most effective.

Fouled heat-exchange surfaces

Soot and scale

The transfer of heat to boiler water is inhibited by the accumulation of soot on the fireside of a heat-exchange surface and scale on the waterside. Fouled heat-exchange surfaces also raise flue gas temperatures and increase heat loss from the stack. To keep heat-exchange surfaces clean of soot and scale, ensure that

- both fireside and waterside surfaces are inspected carefully whenever the boiler plant is shut down;
- boiler feedwater is treated as required to reduce deposits; and
- soot blowers, brushes or manual lances are used as required.

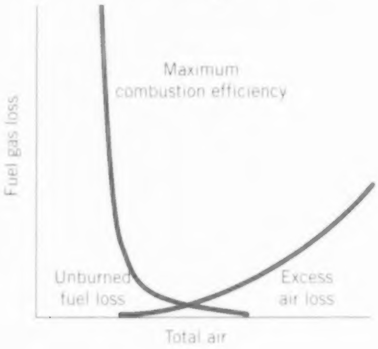
Tip

Determine if there are gaseous process by-products (e.g. waste oxygen, hydrogen, CO, biogas or hydrocarbon streams) available in the plant that could be used as no-cost/low-cost boiler fuel supplements.

A 20°C reduction in flue gas temperature will produce a 1 percent improvement in boiler efficiency.

A scale buildup of 1 mm can increase fuel consumption by 2 percent.

Figure 2.4
Zone of maximum combustion efficiency



Hot blowdown water

Boiler water must be blown down periodically to prevent scale from forming. If blowdown is too excessive, however, heat, water and water-treatment chemicals are wasted. Often, more water is blown down than required to prevent scale formation; in addition, the blowdown is usually scheduled once a day or once a shift, so the amount of dissolved solids immediately after blowdown is far below the maximum acceptable. Total dissolved solids should be tested and the blowdown rate should be adjusted periodically, as minimum measures. If blowdown can be done more often, and in smaller amounts, the solids content can be maintained much closer to the maximum desired.

Once optimum blowdown rates are established, attention can be given to recovering heat from blowdown water. This is usually accomplished in two stages:

- Use a flash tank to generate low-pressure steam from the blowdown (flash steam can be used in other heating applications such as the de-aerator).
- Use the remaining water in a heat exchanger to preheat make-up water.

Heat loss in condensate

Whenever possible, hot condensate from steam-using equipment should be returned to the boiler. The loss of condensate from the steam system increases consumption of water, water-treatment chemicals and the thermal energy needed to heat the make-up water.

Heat may be lost in the form of flash steam that develops when the process pressure – under which the condensate is returned – is released. This may be partly recovered by submerging the condensate return inlet in the tank or by installing a spray condenser fitted to the top of the tank.

A more efficient way is to employ a steam-condensate closed system that allows condensate to return in a closed pressurized loop to be reboiled. Such a system uses less equipment for the steam process and does not suffer any losses. In one particular installation in a Quebec mining company, the energy consumption was reduced by 18 percent when compared with a conventional steam-condensate open system.

Environmental considerations

Energy-saving measures that reduce consumption of boiler fuel reduce emissions of CO_2 and other pollutants into the atmosphere in direct proportion to the amount of the fuel reduction. See Section 1.1, "Climate change," on page 1 for a practical method for calculating emissions reductions resulting from fuel economies.

Tip

Rather than use a set-time blowdown initiation (e.g. daily at 8:00 a.m.) or continuous blowdown, which may be wasteful, it may be more effective to start the blowdown when boiler water conductivity rises to a specific level. Automatic controls that continuously measure boiler water conductivity are now available.

Dumping of condensate also has undesirable environmental impacts:

- Water, chemicals, electrical power and fuel are wasted.
- Water-treatment chemicals are introduced into the environment.
- Hot effluent accelerates the deterioration of sewer pipes and is, therefore, forbidden in most municipalities.

Poor condensate drainage leads to

- water hammer (see page 90);
- increased maintenance;
- poor heat transfer; and
- energy waste.

Low NO_x combustion

Nitrogen oxides, referred to collectively as NO_x, are generated by the reaction of nitrogen and oxygen at high temperature in the boiler combustion chamber. The main source of reactants is fresh combustion air, which is high in oxygen. NO_x production will not necessarily decrease in direct proportion to fuel economies. The most common way to reduce NO_x production is to reduce the flame temperature by one of several techniques, such as the following:

- staged-air combustion, in which combustion air is added to fuel in the burner progressively from several locations; and
- flue gas recirculation, in which some flue gas is returned to the burner, thus reducing the flue temperature and the amount of reactants available to the NO_x reaction.

Much research in the low-NO_x technology done in recent years resulted in the development of burners that reduce NO_x but do not affect thermal efficiency appreciably. The appropriate techniques are fuel type-specific.

With exceptions (see tip at right), the techniques to control NO_x are not designed to save energy, but they do reduce stack emissions, an equally important goal.

Employing the fuel direct injection (FDI) technology, a full-time FDI regenerative (FFR) burner reduces NO_x emissions by about 90 percent compared with ordinary regenerative burners. The compact FFR burner allows simplification and downsizing, along with energy consumption reduction by 40 to 50 percent and a payback period of two years.

Energy management opportunities

The following opportunities are in addition to those previously mentioned in this section.

Housekeeping EMOs

- Regularly check water treatment procedures.
- Operate at the lowest steam pressure (or hot water temperature) that is acceptable to the demand requirements.
- Minimize load swings and schedule demand where possible to maximize the achievable boiler efficiencies.
- Check the boiler efficiency regularly.
- Monitor and compare performance-related data to established standards regularly.
- Monitor the boiler excess air regularly.
- Keep burners in proper adjustment.
- Replace or repair any missing or damaged insulation.
- Periodically calibrate measurement equipment and tune the combustion control system.

Low-cost EMOs

- Install performance monitoring equipment.
- Relocate the combustion air intake.
- Add insulation.
- Reduce boiler excess air.

Retrofit EMOs

Could radiation heat from the boiler shell be used for combustion air preheating as well?

- Install an economizer.
- Install a flue gas condenser.
- Install a combustion air heater.
- Incorporate a heat pump.
- Install a new boiler.
- Upgrade the burner.
- Install the turbulator in the fire tube boiler.
- Convert from oil to gas (more a financial saving than an energy saving).
- Install an electric coil burner.

More detailed information

The technical manual *Boiler Plant Systems* (Cat. No. M91-6/6E), available from NRCan, is a useful reference, although its coverage of automation is not current. See page vi of the preface of this Guide for ordering information.

Boiler plant systems evaluation worksheet

Excess air

Measure the flue gas oxygen with a flue gas analyser.

Oxygen content: _____%; Excess air: _____%

Done by: ______________________ Date: ____________________

Is the gas content of the excess air less than 10 percent? Is the oil content of the excess air less than 20 percent?

☐ Yes Check monthly to maintain standard.

☐ No Consult a burner technician to determine whether the burner can be adjusted to reduce excess air.

Done by: ______________________ Date: ____________________

Is the flue gas free of combustibles?

☐ Yes Check monthly to maintain standard.

☐ No Ensure that a burner technician adjusts the burner to eliminate combustibles.

Done by: ______________________ Date: ____________________

Flue gas heat recovery

Measure flue gas temperature at average boiler load.

Temperature: _____°C; load: _____kg/h

Done by: ______________________ Date: ____________________

Is the system fitted with an economizer or air heater?

☐ Yes At next shutdown

- ensure that the unit is operating and not bypassed;
- calculate the heat recovered and compare against design;
- check fins and tubes for damage, especially from corrosion; and
- remove accumulated soot.

☐ No Contact economizer suppliers to evaluate the potential of installing an economizer.

Done by: ______________________ Date: ____________________

Blowdown heat recovery

Have your water-treatment chemical supplier assess the content of dissolved solids in the boiler water and the frequency of blowdown.

Blowdown rate: _____ kg/h

Temperature: _____ °C

Frequency: every _____ hours

Done by: ______________________________ Date: ______________________

Is there potential for recovering heat from the remaining blowdown water and using it for other purposes?

☐ Yes Consult an engineer.

☐ No No action required.

Done by: ______________________________ Date: ______________________

Would it be a good idea to change the blowdown rate?

☐ Yes Adjust the blowdown rate and frequency.

☐ No No action required.

Done by: ______________________________ Date: ______________________

Return condensate to the boiler

Calculate the percentage of condensate that returns to boilers from steam-using equipment.

Is less than 80 percent of condensate returned to boilers?

☐ Yes Determine whether
- the condensate is clean (i.e. will not contaminate the boiler plant); and
- returning the condensate to the boiler would be economical.

If yes, consider options for returning more condensate to the boiler system.

☐ No Check periodically to see whether situation improves.

Done by: ______________________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.6 Steam and condensate systems

A steam-distribution and condensate-return system should deliver steam efficiently from the boiler plant to heating systems and processing equipment and return condensate to the boiler for re-use. Some energy is always lost from a steam and condensate system, most significantly in steam trap loss. Others include heat loss from piping and fittings (insulated and uninsulated), leaks and flash losses, condensate loss to drain and overall system losses. This section is intended to help you find and correct the sources of energy loss.

Pipe redundancy

Redundant steam pipes serve little or no purpose, yet they are at the same temperature as the rest of the system and so the heat loss per length of pipe remains the same. Moreover, the redundant pipes receive scant maintenance of insulation, leaks and steam traps. In addition, the heat losses from the extra piping add to the space heat load of the facility and thus to the ventilation and air-conditioning requirements.

In any review and rationalization of the steam and condensate network, the first step should be to eliminate redundant pipework. It is estimated that in older facilities it is possible to reduce the length of piping by 10 to 15 percent. Redundant pipework wastes energy.

Over-sized pipes

- increase capital and insulation costs; and
- result in higher surface heat losses.

Under-sized pipes

- require higher pressure;
- result in higher leakage losses; and
- require extra pumping energy.

Steam leaks

Steam leaks at pipe fittings, valves and traps can result in substantial energy losses. Also, water leaked from the system must be replaced and chemically treated, which is a less apparent but still expensive consequence.

Figure 2.5 (page 86) indicates how to calculate the hourly loss from a steam leak by measuring the length of the steam plume, which is the distance from the leak to the point at which water condenses out of the steam.

Steam trap losses

Steam traps are key components of an efficient steam and condensate system. However, because defective traps are difficult to detect, they are also among the chief causes of energy loss. Energy losses from steam traps occur for several reasons:

- the trap fails in the open position and permits live steam to escape;
- the wrong type or size of trap is installed;
- the trap is installed in the wrong place; and
- the method used to install the trap was faulty.

All facilities that use steam for heating or process should implement a regular steam trap inspection and maintenance program.

Throw condensate away – throw money away!

FIGURE 2.5
Hourly steam loss from leaks as a function of steam plume length

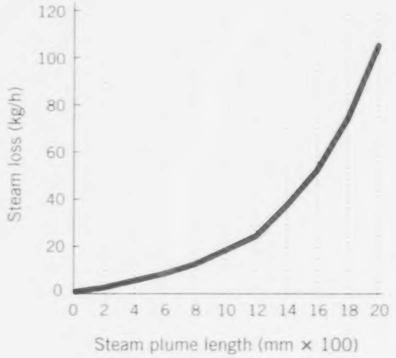
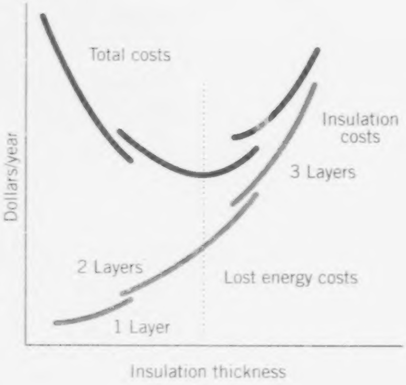


FIGURE 2.6
Determination of economic thickness of insulation



Heat loss through uninsulated pipes and fittings

Bare or improperly insulated steam pipes are a constant source of wasted energy because they radiate heat to the surroundings instead of transporting it to steam-using equipment. The heat losses reduce the steam pressure at the terminal equipment. This situation increases the boiler load because extra steam is required to make up the losses.

All steam pipes should be inspected frequently. Uninsulated steam pipes should be insulated, and the insulation should be inspected and replaced when damaged. Loose-fibre insulation (e.g. mineral and glass fibre, cellulose) loses effectiveness when wet, and outdoor pipes are particularly vulnerable to moisture. Therefore, pipe inspections should cover vapour barriers and weatherproof jackets.

The economic thickness of insulation for steam pipes (i.e. the best compromise between the cost of insulation and the potential savings in energy) is based on the size of the pipe and the temperature of the environment (see Figure 2.6). This concept is discussed in detail in the technical manual *Process Insulation* (Cat. No. M91-6/1E, available from NRCan).

However, energy loss is not restricted to the piping system. Process equipment and terminal heating units can also represent a major source of energy loss.

Environmental considerations

Energy-saving measures that reduce steam leaks and heat loss will reduce the requirement for steam generation. This will, therefore, cut fuel consumption by the boiler and thus also the amount of greenhouse gas emissions. For instructions on calculating the reduction in pollutant emissions from the boiler, see Section 1.1, "Climate change," on page 1.

Energy management opportunities

Housekeeping EMOs

- Set up steam trap maintenance program and procedures.
- Check and maintain proper equipment operation.
- Check and correct steam and condensate leaks.
- Maintain good steam quality (i.e. maintain chemical treatment program).
- Check control settings.
- Repair damaged insulation.
- Shut down equipment when not needed.
- Shut down steam and condensate branch systems when not needed.

A 10-ft. length of uninsulated 10-cm steam pipe will waste more than twice as much money in steam costs per year than it would cost to insulate it with a mineral fibre and aluminum jacket.

Low-cost EMOs

- Improve condensate recovery.
- Overhaul pressure-reducing stations.
- Operate equipment efficiently.
- Insulate uninsulated pipes, flanges, fittings and equipment.
- Remove redundant steam and condensate piping.
- Reduce steam pressure where possible.
- Re-pipe systems or relocate equipment to shorten pipe lengths.
- Repair, replace or add air vents.
- Optimize location of sensors.
- Add measuring, metering and monitoring equipment.

> As little as 1 percent by volume of air in steam can reduce the heat transfer efficiency by up to 50 percent.

A single steam trap, leaking 100-psig steam through an orifice only 0.16 cm in diameter, will lose approximately 48 t of steam per year. That is about 3.4 t/yr. (or 830 imperial gallons) of fuel oil. How much would it cost you?

Retrofit EMOs

- Upgrade insulation.
- Eliminate steam use where possible.
- Institute a steam trap replacement program.
- Optimize pipe sizes.
- Recover flash steam.
- Stage the depressurization of condensate.
- Recover heat from condensate.
- Install closed-loop pressurized condensate return.
- Meter steam and condensate flows.

Ten pairs of uninsulated NPS 6 flanges will cause an annual heat loss of $1,000.

More detailed information

The technical manual *Steam and Condensate Systems* (Cat. No. M91-6/8E, available from NRCan) is a comprehensive treatment of the subject. See page vi of the preface of this Guide for ordering information.

Steam and condensate systems evaluation worksheet

Redundant piping

Examine updated plant piping drawings, if available, or walk through the facility and look for opportunities to rationalize and streamline the steam and condensate network (SCN).

Did you find any unused, redundant piping?

☐ Yes First, ensure that the piping can be isolated from the rest of the system. Then plan on removing the parts that are no longer required.

☐ No No action required.

Done by: ______________________ Date: ______________________

Is the SCN optimized relative to location of the steam-using equipment, pipe sizing and steam delivery requirements?

☐ Yes No action required.

☐ No Have a qualified contractor redesign the SCN to optimize it. If required, consider localization of steam generation/delivery closer to steam-using equipment.

Done by: ______________________ Date: ______________________

Steam leaks

Walk through the facility with appropriate detection equipment (e.g. ultrasonic detector, listening rods, pyrometer, stethoscope) and look and listen for steam leaks.

Did you find any leaks?

☐ Yes Using Figure 2.5 (page 86), estimate the steam loss from leaks.

Arrange to repair all leaks at the first opportunity.

☐ No Check monthly to maintain standard.

Done by: ______________________ Date: ______________________

Can you tell whether any steam is escaping from steam traps and valves?

☐ Yes If steam is escaping, have the leaks repaired as soon as possible.

☐ No Verify correct function by having a qualified contractor or a representative from the manufacturer of your steam traps and valves check the system with an ultrasonic leak detector.

If no steam is escaping, check monthly to maintain standard.

Done by: ______________________ Date: ______________________

Insulation

Walk through the facility and note the existence and condition of pipe insulation.

Are steam pipes insulated?

☐ Yes No action required.

☐ No Have an economic thickness of insulation installed at the first opportunity (refer to the technical manual *Process Insulation* to estimate potential savings).

Done by: ______________________ Date: ____________________

Is insulation dry?

☐ Yes Check monthly to maintain standard.

☐ No Locate the source of the moisture and correct the problem – for example, if the pipe is leaking, repair it.

Replace the insulation.

Done by: ______________________ Date: ____________________

Are the insulation, vapour barrier and jacket intact?

☐ Yes Check monthly to maintain standard.

☐ No Replace damaged material.

Done by: ______________________ Date: ____________________

Is there a more effective insulation material available?

☐ Yes Evaluate the economics of replacing present insulation with another type. Consult with an unbiased professional.

☐ No No action required.

Done by: ______________________ Date: ____________________

Is the insulation thick enough? (Insulation should be cool to the touch.)

☐ Yes No action required.

☐ No Consider adding more insulation (consult the manufacturer or an insulation contractor for advice on whether increasing the amount would be economical).

Done by: ______________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.7 Heating and cooling equipment (steam and water)

In this section, only the indirect heating or cooling will be considered; this refers to situations where steam or cooling water is separated from a receiving product by a membrane.

Steam-heated and water-cooled equipment performs many important process functions, and efficient heating and cooling of process equipment depends on several factors:

- unimpeded heat transfer, both from the steam to the process and from the process to the cooling water, which requires clean heat-transfer surfaces and exclusion of air and condensate from steam;
- rapid removal of condensate from process equipment;
- control of heat losses and gains from process equipment;
- use of process equipment only when necessary; and
- prompt detection and repair of steam and water leaks.

Cleanliness of heat-transfer surfaces

The surfaces between the steam and the product being heated should be kept as clean as possible. Buildup of scale on the steam side or sludge on the process side dramatically reduces the efficiency of heat transfer. In water-cooled equipment, buildup on heat-transfer surfaces causes similar problems.

The sign of this condition in a heating system is an increase in steam pressure; in a cooling system, it is an increase in the flow rate of cooling water. In both cases, the system is working to overcome the reduction in heat-transfer efficiency caused by scale or sludge.

Removing condensate

Steam and condensate must always flow in the same direction.

Problems caused by condensate usually arise because the condensate is prevented from draining away as it forms. Accumulations of condensate inhibit process heating by preventing steam from entering the equipment.

Faulty steam traps, steam coils and heat exchangers are usually the source of condensate problems. With steam traps, the right type and size must be installed, and they must be installed correctly and kept in good working order. Steam coils and heat exchangers also must be installed correctly to ensure that condensate drains efficiently; in a heat exchanger, efficient drainage also ensures that accumulated condensate does not cause water hammer. **Water hammer** refers to a pressure rise in a pipeline caused by a sudden change in the rate of flow or stoppage of flow in the line – such as flash steam being obstructed by poorly draining condensate. The steam pushes the condensate in "slugs" which act like a battering ram. It is accompanied by a sharp "hammering" sound and vibrations that mechanically stress the pipework system, often causing serious damage.

Insulating heating and cooling equipment

Uninsulated heating equipment increases the load on the steam system, which must make up for the heat loss to the surroundings. Applying insulation to the exterior surface of heating equipment reduces the rate of heat loss to the surroundings. To calculate heat loss from equipment and piping, use Figure 2.5 and Figure 2.6 (page 86) and consult Worksheet 9-4 and Worksheet 9-5 in the technical manual *Heating and Cooling Equipment: Steam and Water* (Cat. No. M91-6/9E, available from NRCan).

Uninsulated cooling equipment similarly increases cooling load because the cooling system must also remove heat gained from the environment. Applying insulation to the exterior surfaces of the equipment reduces the rate of heat transfer from surroundings.

Environmental considerations

Efficiency improvements to heating and cooling systems save energy, thus reducing the pollutants emitted by heat-generating boilers at the plant and by boilers at electricity thermal generating stations. For more information, see Section 1.1, "Climate change," on page 1.

Energy management opportunities

Housekeeping EMOs

- Repair leaks.
- Check and maintain the integrity of insulation.
- Maintain the correct function of instruments.
- Check and maintain steam separators and steam traps.
- Clean heat-transfer surfaces.
- Check and maintain steam quality.
- Reduce steam temperature and pressure where possible.
- Slope heating coils to remove condensate.

Low-cost EMOs

- Shut down equipment.
- Lock controls.
- Operate equipment at capacity.
- Install thermostatic air vents.
- Add measuring and monitoring devices.
- Access control device locations.

Retrofit EMOs

- Convert from indirect to direct steam heating where justified.
- Install/upgrade insulation.
- Use equipment heat for building heating.
- Stabilize steam and water demand by reviewing process scheduling so as to flatten the peak demands.
- Recover heat from waste streams – choose from options available (including heat pumps).

More detailed information

The technical manual *Steam and Condensate Systems* (Cat. No. M91-6/8E) is available from NRCan. See page vi of the preface of this Guide for ordering information.

Heating and cooling equipment evaluation worksheet

Heat transfer

Inspect the condition of heat-transfer surfaces at the next opportunity, and note the steam temperature and pressure and the cooling water temperature and flow.

Are heat-transfer surfaces clean and free of scale?

☐ Yes Check periodically to maintain standard.

☐ No Remove scale and fouling at the first opportunity to restore heat-transfer effectiveness.

Institute a regular cleaning program and procedure.

Done by: ______________ Date: ______________

If the steam pressure or temperature seems higher than the process requires, can it be reduced without affecting other steam equipment?

☐ Yes Check that process requirements have not changed.

Check that heat-transfer surfaces are clean.

If possible, reduce the supply pressure.

☐ No No action required.

Done by: ______________ Date: ______________

Condensate system

Inspect steam traps on steam-heated equipment.

Are the traps the right size and type for the application? Are they installed according to the manufacturer's specifications?

☐ Yes Check each steam trap to ensure that it is not leaking and is operating correctly.

☐ No Replace inappropriate traps with traps of the correct type.

Re-install traps that are incorrectly installed.

Done by: ______________ Date: ______________

Observe heat exchanger and steam-coil installation.

Are coils and heat exchangers oriented to permit condensate to drain correctly? Are the gaskets intact?

☐ Yes No action required.

☐ No Ensure that coils and heat exchangers are re-oriented as soon as possible.

Replace gaskets and institute a preventive maintenance program.

Done by: ______________ Date: ______________

Insulation

Check the condition of the insulation on all steam-heated and water-cooled equipment.

Is all steam-heated and water-cooled equipment insulated?

☐ Yes Ensure that the equipment is covered with an economic thickness of insulation.

☐ No Install an economic thickness of insulation on all uninsulated equipment (refer to *Process Insulation*, Cat. No. M91-6/1E).

Done by: ______________ Date: ______________

Is insulation clean, dry and intact?

☐ Yes Check periodically to maintain standard.

☐ No Locate source of moisture and repair leaks.
Repair or replace damaged insulation.

Done by: ______________ Date: ______________

Operation and maintenance

Observe the equipment in operation.

Is steam or cooling water flowing to equipment that is not in use?

☐ Yes Shut off the steam or water supply to idle equipment.

☐ No No action required.

Done by: ______________ Date: ______________

Does steam, condensate or cooling water leak from any equipment or any supply pipes?

☐ Yes Repair leaks as soon as possible.

☐ No Check frequently to maintain standard.

Done by: ______________ Date: ______________

Can well water be substituted for chilled water?

☐ Yes Have an expert design a well-water-based cooling system.
Consider integrating a ground-source heat pump instead.

☐ No No action required.

Done by: ______________ Date: ______________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.8 Heating, ventilating and air-conditioning systems

Facilities are served by many different kinds of heating, ventilating and air-conditioning (HVAC) systems, both for human comfort and to meet process requirements. HVAC systems are generally designed to compensate for heat loss and heat gain and to provide ventilation and control of temperature and humidity.

An energy management program for an HVAC system should begin with an assessment of the established HVAC systems to determine their type, function and operating procedures. This assessment will help identify areas of energy waste and opportunities to improve efficiency.

In some cases, more energy cost savings will be realized from HVAC improvements than from any other improvements made in the facility.

Since HVAC systems vary widely from plant to plant, performance improvements and energy cost savings will also vary widely. Three important factors determine the energy use of an HVAC system:

- the required indoor thermal quality and air quality;
- the internal heat generation from lighting and equipment; and
- the design and layout of the building.

It takes 40 kW of energy to heat 1 m^3 of air from −12°C to 21°C.

Aspects of HVAC and building design cannot really be dealt with separately since they affect one another. This is reflected in other programs offered by Natural Resources Canada's Office of Energy Efficiency, such as the Commercial Building Incentive Program and the C-2000 Program for Advanced Commercial Buildings.

Energy management opportunities

Housekeeping EMOs

Improving energy-related housekeeping practices is the obvious place to start an energy cost-reduction plan. This happens, to a large degree, by changing people's habits and promoting awareness of energy savings. Here are some of the activities, which cost little or nothing in capital outlay:

- Shut down unneeded equipment during idle or unoccupied periods.
- Shut off lights, computers, photocopiers and other heat-producing equipment when not required; upgrade lighting technology.
- Consider increased use of (northern) daylighting, where possible.
- Check and recalibrate control components such as room thermostats, air and water temperature controllers, set them properly and verify setting of time clocks.
- Establish minimum and maximum temperatures for heating and cooling during occupied and unoccupied periods and re-adjust controls accordingly.
- Adjust airflow rates to suit changing occupancy conditions and use of building space.
- Ensure that vents are open in summer and closed in winter.
- Adjust and tighten damper linkages.

- Check and adjust motor drives on fans and pumps for belt tension and coupling alignment.
- Prevent restrictions of airflow by checking/replacing air system filters.
- Shut off exhaust and make-up air systems to areas such as kitchens and laundries when they are not in use.
- Replace damaged or missing insulation on piping and duct systems.
- Replace or repair crushed or leaking ducts in the air system.
- Clean heat exchange surfaces, heating units and heating coils.

Tip

Implement a planned maintenance program to minimize an HVAC system's component failures.

Tip

Consider upgrading windows and doors: double- or triple-glazed low-emissivity insulating windows, reflective coating on windows, and insulated doors.

Cost-reduction measures

One of the major sources of waste is heating or cooling excess amounts of outdoor air. Excess outdoor air enters buildings by infiltration and through HVAC systems.

Reduce heat gain

Reducing heat gain in air-conditioned spaces will reduce the energy used for cooling. Heat gain can be reduced by the following measures:

- Improve building fabric (e.g. insulation, solar shading).
- Shield the building with shade trees.
- Reduce lighting where possible (i.e. upgrade the lighting system).
- Consider increased use of daylighting (particularly northern light).
- Add insulation to hot surfaces.
- Isolate heat-generating equipment and provide local exhaust and make-up air.
- Block unneeded windows.

Reduce heat losses

Reducing losses of space heat saves heating energy and leads to improved working conditions and higher worker productivity. Where they apply, the following measures work well:

- Improve building insulation.
- Insulate cold conduits such as pipes and ducts.
- Block unneeded windows.
- Upgrade windows and doors (see tip at left).
- Control air leakage out of the facility (exfiltration).

Reduce humidification requirements

The amount of humidification required in an industrial environment is usually dictated by the process and may require considerable energy.

- Examine current humidification levels for human comfort and production requirements – can they be lowered?

In winter, it takes 14.6 kW of energy to increase the humidity of 1 m^3 of outdoor air to 40 percent relative humidity at 21°C.

- Make frequent cleaning and monitoring of water used for humidification a part of routine maintenance to ensure efficient operation and to avoid damage to other HVAC components.
- Consider using high-pressure water atomization instead of compressed air humidification for substantial energy savings (e.g. a company replaced a 140-hp compressor dedicated to humidification with a 7.5-hp pump required for atomization).

In Ontario alone, more than $600 million is spent annually to heat make-up air for buildings.

Implement an energy management system

For most plants, warehouses and offices that operate less than 24 hours per day or seven days per week, energy savings can be realized from temperature setbacks and reductions in ventilation rates. Depending on the complexity of the HVAC system, implementing an energy management system may be as simple as installing programmable thermostats or as elaborate as installing full direct digital controls.

- Install self-regulating controls for the lighting and ventilation systems.
- Interconnect the controls for spaces with separate heating and cooling systems to prevent simultaneous heating and cooling.
- Install load analysers in the controls of multi-zone and dual duct systems to optimize hot and cold deck temperatures.
- Install load analysers in the controls of terminal reheat systems to optimize the supply air temperature and minimize the reheat load.

Other low-cost EMOs

- Install time clocks to shut down the air system or switch to 100 percent recirculation when the space served is unoccupied.
- Install control interlocks to shut down heating or cooling system pumps when no output is required.
- Install economizer controls on the central air handling system to use outdoor air to replace refrigerated cooling when appropriate.
- Add automatic control valves at unit heaters and fan-coil heaters to shut off the flow of water or steam when fans are not running.
- Consider installing variable-speed drives to a centrifugal chiller – savings of up to 40 percent versus a conventional chiller may be possible.
- Provide lockable covers on automatic controls and thermostats to prevent unauthorized adjustment or tampering.

CANMET assisted a small Canadian firm to develop a system that uses a heat pump for reclaiming low-grade heat lost through ventilation and returning it to service. The system reached a seasonal coefficient of performance (COP) of up to 5.2.

Retrofit EMOs

Heat recovery

An effective way to cut HVAC energy costs is to apply heat recovery technology. However, *the biggest problem with these systems is maintenance.* Often in a plant environment, the prime effort goes into maintaining production to the detriment of everything else, and that includes the maintenance of heat recovery systems. A poorly maintained heat recovery system may eliminate energy savings and lead to deterioration of indoor air quality.

Heat recovery involves reclaiming heat from the building and from process exhaust air and using it to heat make-up air in winter and to cool make-up air in summer. Both latent heat and sensible heat can be recovered and, if the plant is humidified, may provide considerable savings. The following conditions produce the highest payback with a heat recovery system:

- high-volume, high-temperature differential exhaust, especially if localized;
- high indoor humidity requirements;
- low internal heat generation in the plant; and
- existence of a ducted make-up air system.

A heat recovery system should be considered if at least one of these conditions is fulfilled; it may then be economical. Usually, recovery of 65 percent of exhaust heat can be accomplished with a reasonable payback period. However, recent developments now allow heat recovery from even small temperature-gradient streams, and a suitable application should be investigated.

Among the major types of heat recovery equipment are:

- heat-recovery wheel;
- heat-pipe heat exchanger;
- stationary surface air-to-air heat exchanger;
- run-around glycol-loop heat recovery; and
- heat pump-based systems.

Each type has advantages and disadvantages. The most suitable type should be selected after a thorough analysis of the proposed application.

In a situation where quick response to heating/cooling demands was required, electric reversible heat pumps were installed – each pump capable of working as a heater or chiller – together with a heat recovery unit. Capital, operational costs and energy consumption were greatly reduced.

Equipment upgrades

Modifying or converting an established, inefficient HVAC system to improve efficiency will save energy. Here are some examples:

- Utilizing adjustable speed drives for fans and pumps will improve the HVAC system's operating efficiency and reduce costs.
- Converting constant volume, terminal reheat systems into variable air volume (VAV) systems saves fan energy as well as heating and cooling energy. Multi-zone and dual-duct systems also present opportunities for savings by conversion to VAV systems.
- In areas where heat losses are high, such as in shipping and receiving areas and vehicle repair bays, replacing conventional convection heating systems

with gas-fired infrared heaters will save energy. With the radiant heating system, space temperatures can be kept much lower without reducing occupants' comfort.

- Replace electric resistance heaters – the most expensive form of space heating – with an alternative source, such as direct or indirect gas firing or (where possible) boilers.
- For chilled water systems, several options exist:
  - Cooling towers and plate-type heat exchangers can be installed.
  - In Canada, well water is generally cold enough to replace chilled water; this year-round supply of constant-temperature water can provide energy savings of about 75 percent. In new systems, this method may also save capital costs.
  - Increasingly, the application of ground-source heat pumps may provide the most efficient system with several side benefits.

Free cooling in the form of economizers for rooftop units and air-handling systems can be used to eliminate the need for refrigeration in winter.

Alternative energy sources

Energy costs can be reduced if expensive sources can be replaced with cheaper forms. Very often, this option is overlooked. Certainly, alternative sources of energy should be investigated in light of the advances made in the various technologies worldwide, and by NRCan's Canada Centre for Mineral and Energy Technology (CANMET), which offers a wealth of information (see Appendix C of this Guide on page 183).

Solar energy

"Solar walls" and similar new devices use solar energy to temper outdoor air in winter with reasonable payback periods. The Canadian-developed, patented Solarwall® is a metal collector designed to provide preheated ventilation (make-up air) for buildings that have large south-facing walls. It captures solar energy, provides additional insulation to the building and de-stratifies indoor air. Paybacks as short as one year are possible.

Ground-source heat pumps

The heat contained in ground water may be used at little or no cost for both the HVAC and process heating purposes. There have been many developments that employ ground-source heat pumps singly or in combination with other systems. The use of the systems range from heating water in a fish hatchery in Canada to providing up to 88 percent of heating and cooling needs of a large hospital and housing development in Sweden and Norway respectively.

Radiative and evaporative cooling; thermal storage

During no-frost periods in Canada, cooling water from HVAC systems can be chilled through radiation and evaporation by spraying it over a flat or low-slope surface, particularly at night. The chilled water is subsequently filtered, stored and delivered for next day cooling, thereby enabling downsizing of conventional cooling systems. Net cooling-energy savings of more than 50 percent have been reported.

Note: This should not be confused with the practice of spraying or flooding hydrant water over flat roofs of buildings on hot days to provide evaporative cooling for the interior. Such practices waste water.

Waste heat from process streams

A fresh look at this kind of opportunity in a plant may lead to surprising savings. For example, a chemical manufacturer was able to modify its processes and recover a portion of heat from process cooling water normally sewered and use it in preheating make-up air in a number of buildings. The simple payback period was less than four years.

Other retrofit EMOs

- Install local air treatment units (e.g. electronic air cleaners, activated charcoal odour-absorbing filter, high-efficiency filters) to allow increased (perhaps up to 100 percent) recirculation of indoor air and reduction of outdoor air required for ventilation.
- Install a separate air system to serve an area that has a unique requirement that would affect the operation of a large central system (e.g. areas that have large heat gain or fluctuating occupancy).
- To reduce overall ventilation, reduce building airflow rates by moving conditioned air from spaces that require a high-quality environment through spaces that have less demanding requirements.
- Install a computerized energy management system to monitor and integrate the control function of the building's energy systems including lighting and HVAC.
- Consider a new heat pump system instead of a new air-conditioning system if winter heating is required. The higher equipment costs will be offset by reduced heating costs during the winter season.

Environmental considerations

Energy savings in HVAC systems – and thus reduced pollutant emissions – result from reducing energy consumption for space heating and cooling, humidification and dehumidification, and driving fans and pumps. See Section 1.1, "Climate change," on page 1 for information about calculating reductions.

When designing the plant for an HVAC system, pay particular attention to the cooling plant. This typically involves more capital investment than the heating plant, and the refrigerants used may also pose an environmental problem. Canada, as a signatory to the 1987 Montreal Protocol on ozone-depleting substances, is committed to regulating and phasing out emissions of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) that include common refrigerants. Due care must be taken in selecting and handling the refrigerants and repairing the leaks (perhaps uncovered by an energy audit of an HVAC system), as per federal and provincial regulations.

This Guide does not cover CFCs because they are released into the environment through leakage and are, therefore, a maintenance issue rather than an energy-use issue.

More detailed information

The technical manual *Heating, Ventilation and Air Conditioning* (Cat. No. M91-6/10E, available from NRCan) is dated, but it remains a good reference. See page vi of the preface of this Guide for ordering information.

Heating, ventilating and air-conditioning systems evaluation worksheet

Housekeeping

Check operation of supply and exhaust fans, air-conditioning units, pumps and make-up air units.

Is any equipment operating in unoccupied areas?

☐ Yes Shut down equipment when it is not needed.

Install timer controls to turn equipment off after working hours.

☐ No Check monthly to maintain standard.

Done by: ______________________ Date: ______________________

Check thermostat settings.

Are settings appropriate for the season (e.g. 22°C in winter and 24°C in summer)?

☐ Yes Calibrate thermostats in the spring (beginning of air-conditioning season) and in the fall (beginning of heating season).

☐ No Set the thermostats at the lowest acceptable setting in winter and the highest acceptable setting in summer.

Done by: ______________________ Date: ______________________

Do thermostats have night setback capability?

☐ Yes Check setback temperatures: in winter, they should be 2–3°C lower than the daytime setpoint temperature; in summer, they should be 2–3°C higher than the daytime setpoint temperature.

☐ No Install setback thermostats in areas that are not occupied overnight or on weekends.

Done by: ______________________ Date: ______________________

Check belt tension on fans and pumps.

Are belts properly tensioned and aligned?

☐ Yes Check monthly to maintain standard.

☐ No Adjust belt tension and align couplings.

Done by: ______________________ Date: ______________________

Check seasonal vents, dampers and damper linkages.

Are vents closed? Do dampers close tightly?

☐ Yes Check at least once each season to maintain standard.

☐ No Repair or replace linkages that do not work and dampers that do not seal tightly.

Done by: ______________________ Date: ____________________

Energy cost reduction measures

Check for negative pressures and infiltration.

Is the building under negative pressure?

☐ Yes Check for an imbalance between exhaust and make-up air; if you find an imbalance, consider installing a make-up air system.

☐ No Check for stratification.

Done by: ______________________ Date: ____________________

Is infiltration present?

☐ Yes Find the leaks and close them with caulking or weatherstripping.

Consider installing low-leakage dampers at air inlets and air locks, or air curtains at entrances.

☐ No Check at least once per year to maintain standard.

Done by: ______________________ Date: ____________________

Review outdoor air quantity.

Is the outdoor air quantity more than what the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends or more than is required for process or dilution of contaminants?

☐ Yes Consider steps to reduce outdoor air quantity.

☐ No No action required.

Done by: ______________________ Date: ____________________

Check for stratification.

In winter, does the indoor temperature vary more than 6°C from floor to ceiling?

☐ Yes Consider steps to reduce stratification.

☐ No Check at least once per year to maintain standard.

Done by: ______________________ Date: ____________________

Check for pressure losses in fan and pump systems; compare with original design specifications.

Are pressure losses greater than indicated in manufacturer's specifications?

☐ Yes Replace filters.

Clean heating and cooling coils and strainers.

Identify and correct bottlenecks in ducts and pipes.

☐ No Check monthly to maintain standard.

Done by: ______________________ Date: ______________________

Check for excessive cooling load in air-conditioned areas.

Are insulation and solar shading adequate? Are all the windows needed?

☐ Yes No action necessary.

☐ No Consider upgrading insulation and improving shading of windows.

Block unneeded windows.

Done by: ______________________ Date: ______________________

Are any surfaces hot to the touch? Does any equipment generate so much heat that you can feel it?

☐ Yes Add insulation.

Consider isolating heat-generating equipment in an area that can be specially exhausted and supplied with make-up air.

☐ No No action necessary.

Done by: ______________________ Date: ______________________

Check for excessive heating load.

Is building insulation adequate? Are all the windows needed?

☐ Yes Add insulation.

Block unneeded windows.

Upgrade window and door quality.

☐ No No action necessary.

Done by: ______________________ Date: ______________________

Retrofit

Review plant operations and HVAC systems.

Are savings achievable by temperature and ventilation rate setback?

☐ Yes Consider implementing an energy management system or adding these functions to an existing system.

☐ No No action required.

Done by: ______________________ Date: ______________________

Check heat recovery opportunities.

Is there high-volume exhaust at room temperature or higher?

☐ Yes Consider installing a heat-recovery system to preheat and precool make-up air.

☐ No No action required.

Done by: ____________________ Date: ____________________

Check the feasibility of using a variable air volume system.

Is the existing HVAC system a constant-volume, terminal reheat type?

☐ Yes It may be economical to convert the system to a variable air volume type (consult an engineer).

☐ No No action required; check again when fuel or equipment costs change.

Done by: ____________________ Date: ____________________

Check the feasibility of cooling with a ground-source heat pump.

Does your air-conditioning system consume a great deal of energy?

☐ Yes Consider obtaining expert engineering advice on using a ground-source heat pump for space cooling and heating needs.

☐ No No action required.

Done by: ____________________ Date: ____________________

Do your process cooling chillers consume a great deal of energy?

☐ Yes Consider obtaining expert engineering advice on using a ground-source heat pump for process cooling.

☐ No No action required.

Done by: ____________________ Date: ____________________

Check alternative energy sources.

Is electric space heating widely used? Do you use large quantities of energy to heat intake air?

☐ Yes Consider changing to natural gas-fired heating.

Consider using a ground-source heat pump and/or solar heating and/or waste heat from process streams and/or off-peak thermal storage to warm intake air.

☐ No No action required; check again when fuel or equipment costs change.

Done by: ____________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.9 Refrigeration and heat pump systems

Industry uses refrigeration for storage and for processing. The main purpose of a refrigerating system is to remove heat from a process and discharge it to the surroundings.

An energy management program for a refrigeration system should begin with an assessment of the local temperatures, process requirements, refrigeration equipment and systems to identify areas of energy waste and opportunities to improve efficiency. In refrigeration, there are only a few basic ways to save energy, and the following questions should be asked:

- Can we do away with some refrigeration needs?
- Can we remove/reduce some of the refrigeration loads?
- Can we raise the refrigeration temperatures?
- Can we improve the way the refrigeration plant operates?
- Can we reclaim waste heat?

The purpose of the following brief mention of industrial heat pumps (IHPs) is to alert the reader to the many advantages that this relatively new technology offers and to stimulate the integration of IHPs into the wider process heating system.

> It is commonly found that refrigeration systems in service are using 20 percent more energy than they should.

IHPs are devices that use low-grade heat (such as waste-process heat or water, or ground heat) as the heat sources and deliver this heat at higher temperatures for industrial process for heating or pre-heating. Some IHPs can also work in reverse, as chillers, dissipating process heat as well.

The types of heat pumps include

- air-to-air;
- water-to-air;
- air-to-water; and
- water-to-water.

The latter category, used in ground-source heat extraction (or dissipation) applications, is increasingly being considered for applicability.

Perhaps because of the newness of the technology – or the lack of IHP knowledge among engineering firms and target industries or the small numbers of available demonstration projects – the wider use of IHPs is only beginning. Yet, using an IHP system is a valuable method of improving the energy efficiency of industrial processes, which contributes to reducing primary energy consumption. Its application should be considered by Canadian industry. Some very interesting and remarkably efficient systems have been devised in countries as diverse as Canada, Sweden and Japan for a range of industrial applications.

The major categories of IHPs can be described as follows:

- closed compression cycle, driven by
  - electric motor
  - diesel engine;
- absorption cycle, of two types:
  - heat pump
  - heat transformer;
- mechanical vapour recompression (MVR); and
- thermal vapour recompression (TVR).

To discuss these systems is beyond the scope of this Guide. However, a knowledgeable consulting engineer can help in selecting and designing the most suitable system for a given application.

Energy management opportunities

Housekeeping EMOs

There are numerous opportunities for energy and dollar savings in industrial refrigeration. Typically, industrial refrigeration merits little attention and is poorly understood compared with boiler plants. To improve the situation – i.e. learning to identify the losses of energy and then reducing these losses – is good energy management.

Improving energy-related housekeeping practices is the obvious place for an energy cost-reduction plan to start. Housekeeping measures generally involve the following activities, which cost little or nothing in capital outlay:

- Operators may lack proper understanding of refrigeration efficiency issues – educate and train them first.
- Be vigilant in addressing operation and maintenance issues as they arise.
- Establish a regular testing program so that problems are quickly identified.
- Establish maintenance and preventive maintenance programs.
- Clean heat-transfer surfaces (evaporator, condenser) frequently.
- Inspect insulation on suction lines frequently and repair damage promptly.
- Calibrate controls and set temperatures to the highest acceptable levels.
- Keep refrigerant charges at specified levels; eliminate leaks.
- Ensure free circulation of air around condensing units and cooling towers.
- Ensure that heating and cooling systems are run simultaneously only when absolutely necessary.
- Eliminate ingress of moisture to refrigerated rooms from ambient air and water hoses (remember that to evaporate one litre of water requires approximately 500 kg of refrigeration energy).
- Keep the doors to refrigerated areas closed.
- Ensure that controls for defrosting are set properly and review the setting regularly.
- If water for condensers is supplied from cooling towers, ensure that they are effectively maintained to obtain the lowest water temperature possible.
- Measure the compressor coefficient of performance (COP) and the overall system's COP, which includes auxiliary equipment.

Tip

Review your refrigeration plant regimen frequently as process requirements and ambient weather conditions change.

Tip

Ensure that defrosting operates only when necessary and for as short a period as necessary.

Tip

Reduce the power peak demand charge by operating the refrigeration system during off-peak hours where possible.

In a typical centrifugal chiller installation that uses a cooling tower to chill water to 4°C, power requirements can be reduced by about 17 percent if the temperature of the entering water is reduced from 29.4°C to 23.9°C.

A 1°C increase in condensing temperature will increase costs 2–4 percent. A 1°C reduction in evaporating temperature will increase costs 2–4 percent.

Incorrect control of compressors may increase costs by 20 percent or more. Poor control of auxiliary equipment can increase costs by 20 percent or more.

- Check for buildup of non-condensable gases and air on a regular basis to ensure that the plant operates at high COP.
- Check for the correct head pressure control settings.
- Use low ambient temperatures to provide free cooling to suitable loads during winter and shoulder seasons.

Cost-reduction measures

A refrigeration system is analogous to a pumping system that pumps water from a low level to a high level. The higher the pump has to lift the water, the more energy it consumes per unit volume of water. Most cost-reduction measures for refrigeration systems are designed to increase the difference between the temperatures at which condensation and evaporation take place, thereby increasing the COP. The following cost-reduction measures increase the COP by reducing or allowing the reduction of condensing temperatures:

- De-superheat vaporized refrigerant by use of a heat exchanger or by injecting liquid refrigerant into the hot gas discharge (enhances condenser efficiency).
- Use floating head pressure.
- Use liquid pressure boost to allow further reduction in condensing pressure.
- Move the outdoor condenser coil into a clean, cool exhaust-air system.
- Equip the cooling tower with an automatic water-treatment system.

The following cost-reduction measures increase the COP by increasing evaporation temperature:

- Set the evaporator temperature as high as the process permits.
- Install automatic controls to use higher evaporator temperatures under part-load conditions.

Other cost-reduction measures are designed to fine-tune controls to operate the system at peak efficiency, thus reducing heat gain and peak electricity demand. Some of these cost-reduction measures are as follows:

- Upgrade automatic controls in refrigeration plants to provide accurate readings and to permit flexible operation.
- Reschedule production cycles to reduce peak electricity demand.
- Install variable-speed drive fan motors on cooling towers, evaporative coolers and air-cooled condensers.
- Upgrade insulation.
- Replace inadequate doors to cold areas.
- In winter, operate evaporative coolers and condensers with dry coils to eliminate heat tracing and pan heating.
- Consider eliminating hot gas bypass by cycling the refrigeration system.
- Avoid the use of compressor capacity control systems, which throttle the inlet gas flow, raise the discharge pressure or use hot gas bypass.

Other low-cost tips for increasing energy efficiency in refrigeration are as follows:

- Consider installing an automatic purge system for air and non-condensable gases. A purger will not only save energy but reduce refrigerant loss and the running hours of the compressor with consequent savings in maintenance costs.
- Install and maintain traps to remove oil and water from the ammonia in such systems. Contaminants in the ammonia raise the boiling point.
- Provide lockable covers on automatic controls and thermostats to prevent unauthorized adjustment or tampering.

> Gas bypassing expansion valves may add 30 percent or more to your costs.

Ground-source heat pumps

Another way to increase system efficiency is to use ground-source heat pumps to chill water for use in refrigeration compressors instead of using cooling towers. It can improve the COP significantly.

Tip

Install an automatic suction pressure control system to modulate the suction to match production requirements and yield savings.

Retrofit EMOs

Retrofitting may present opportunities for the greatest energy savings but it requires a more detailed energy analysis and the capital cost is usually higher. Retrofitting permits more radical ways to save energy, such as the following:

Matching the compressor to the required duty

Use the best compressors suited for duty at any given time.

Sequence the compressors on the basis of the load and their respective efficiencies. Correct sequencing is most important in the case of part loads.

Ensure that only one compressor operates at part load.

If a choice of compressors exists for part-load operation, use a reciprocating compressor instead of a screw or centrifugal compressor, which has poor part-load performance.

Switching to a different energy source

Internal combustion engines or turbines fuelled with natural gas, diesel or other fuels can replace electric motors to drive refrigeration compressors. This may provide a less expensive energy input and has a better part-load efficiency than electrical motors. Moreover, it may help to reduce the peak power demand. The capital and maintenance costs of replacing prime motors are often too high to justify; however, since the combustion-driven unit affords heat recovery from the engine/turbine jacket and exhaust to supply other heating loads, overall cost savings can be achieved.

Tip

Consider installing split suction for high-and low-temperature requirements.

Tip

Consider using an expert computer control system for management of the refrigeration system – see Section 2.13 (page 140).

Absorption refrigeration

The most promising alternative to mechanical refrigeration is absorption chilling, which does not require electrical energy input. It becomes more economical when reject heat from plant processes or a cogeneration system is available. Energy savings may offset the comparatively high cost of absorption equipment.

Using thermal coolant storage

Thermal coolant storage saves energy by permitting the use of smaller refrigeration equipment operated at peak efficiency for long periods.

Thermal storage is most useful in facilities where the cooling load tends to peak. A plant where the cooling load is constant for more than 16 hours per day cannot benefit from thermal storage.

Coolant storage, using ice tanks, eutectic salts or supercooled secondary refrigerant will maximize the use of night-rate power. It will also reduce the requirement for additional chiller capacity if increased cooling demand is needed. Thermal storage reduces compressor cycling and allows continuous operation at full-load and higher efficiency.

Reclaiming condenser heat

Heat reclaimed from the refrigeration cycle can be used for domestic water heating, space heating or process heating. Also, the system COP may improve when a cooler condenser medium is available. Here are some ways to use reclaimed heat:

- Recover heat from superheated refrigerant vapour to offset energy required for process heat or to heat make-up water.
- Preheat domestic or process water.
- Melt snow.
- Provide heat under slab-based buildings such as garages and rinks, thus preventing frost damage to the slab.

Other methods

Providing decentralized systems in which loads are distributed according to local requirements can usually save energy. For example, if a large system operates at a low evaporator temperature when only a small portion of the load requires low temperature, a small low-temperature system can be installed to serve the special area; the main system can operate at a higher evaporator temperature, improving its COP.

It is estimated that 10 percent of all energy consumed in Canada is used to produce cold.

Other retrofit EMOs

- Segregate refrigeration systems according to temperature; optimize the thermodynamic balance of the refrigeration cycle to dedicate equipment to the minimum required conditions for each process.
- For refrigeration systems that use hairpin coils, consider the use of computer-controlled expansion valves and a monitoring system to substantially save electrical energy.
- Consider installing a closed loop system for cooling compressors and condensers.
- Consider replacing shell-and-tube exchangers with high-efficiency plate heat exchangers.
- Make a reasoned, forward-looking choice between 1) using well, river or lake water (where available) as a lower-temperature cooling medium to reduce condensing temperatures and 2) a ground-source heat pump system.
- Use a heat pump to upgrade the low temperature waste heat to a temperature suitable for building heating or process uses.
- Consider adapting an ice-pond system for reliable, low-cost, non-CFC industrial process cooling, at less than 20 percent of the operating energy costs associated with conventional mechanical compression systems. It integrates the benefits of biological ice-nucleators, optimized water atomizing and microcomputer process automation with conventional outdoor ice-manufacturing techniques.
- Consider using only water as a refrigerant for process cooling water (e.g. plastic injection). Energy savings of 20 to 50 percent are possible.
- Consider deriving a "free cooling" capacity directly from cold open air (e.g. in the winter), thus avoiding the use of a compressor and therefore electricity.
- Consider installing secondary refrigeration using volatile fluids at low temperatures.

Environmental considerations

Energy savings in refrigeration or heat pump systems involve reducing purchases of electricity, usually for compressors, fans and pumps. The reduced electrical load means that boilers at thermo-electricity-generating stations can fire at a slightly reduced rate, which lowers pollutant emissions. See Section 1.1, "Climate change," on page 1 for more information on emissions reductions.

An energy audit may reveal refrigerant leaks from HVAC equipment. Repairing the leaks reduces the quantity of harmful CFCs or HCFCs used as refrigerants that may leak into the atmosphere and damage the Earth's ozone layer. See Section 2.8, "Heating, ventilation and air-conditioning systems," on page 95 for more information.

More detailed information

The technical manual *Refrigeration and Heat Pumps* (Cat. No. M91-6/11E, available from NRCan) is rather dated, but it remains a good reference. See page vi of the preface of this Guide for ordering information.

Refrigeration and heat pump systems evaluation worksheet

Housekeeping

Check heat-transfer surfaces (e.g. evaporators and condensers).

Are tubes and surfaces clean?

☐ Yes Check periodically to maintain standard, more frequently if the operating environment is not clean.

☐ No Clean surfaces; schedule regular cleaning.

Done by: ____________________ Date: ____________________

Check insulation on refrigerant piping and exterior of evaporators.

Is insulation adequate, dry and intact?

☐ Yes Check every six months to maintain standard.

☐ No Repair or replace damaged insulation; if necessary, add more insulation to reduce heat gain.

Done by: ____________________ Date: ____________________

Check thermostat settings.

Are settings correct?

☐ Yes Calibrate thermostats every six months.

☐ No Set the thermostat to the highest acceptable operating temperature.
Calibrate every six months.

Done by: ____________________ Date: ____________________

Check refrigerant charge.

Is refrigerant charge correct?

☐ Yes Check regularly to maintain standard.

☐ No Add or remove refrigerant.
Recheck periodically.

Done by: ____________________ Date: ____________________

Check air movement around condensing units and cooling towers.

Is airflow around the condenser restricted?

☐ Yes Remove restriction or relocate condenser.
Follow manufacturer's recommendations.

☐ No No action required.

Done by: ______________________ Date: ____________________

Check operation of heating and cooling systems.

Do heating and cooling systems operate simultaneously in the same area?

☐ Yes Relocate thermostat, isolate process, etc.

☐ No No action required.

Done by: ______________________ Date: ____________________

Low-cost measures

Investigate possibility of de-superheating.

Can de-superheating be used to reduce condensing pressures?

☐ Yes Implement the most cost-effective method.

☐ No No action required.

Done by: ______________________ Date: ____________________

Investigate possibility of using floating head pressure.

Can head pressure be reduced without adversely affecting the system?

☐ Yes Determine the lowest pressure that can be used and reset accordingly.

☐ No Investigate limiting factors.
Consider using refrigerant liquid pressure booster pumps to overcome line pressure losses and thermal expansion valve pressure drop.

Done by: ______________________ Date: ____________________

Examine location of outdoor condenser coil.

Is there a cool air exhaust opening?

☐ Yes Consider moving condenser coil into cool air stream.

☐ No No action required.

Done by: ______________________ Date: ____________________

Review evaporator temperature.

Can evaporator temperature be increased without adversely affecting the process?

☐ Yes Reset evaporator temperature as high as possible.
☐ No No action required.

Done by: ______________________ Date: ______________________

Review cooling loads.

Does system operate at part load for part of the day?

☐ Yes Install automatic controls to provide flexibility and to use higher evaporator temperatures during part-load conditions.
☐ No No action required.

Done by: ______________________ Date: ______________________

Review production cycle.

Can the production cycle be rescheduled to off-peak hours?

☐ Yes Change schedule to run the system during off-peak hours.
☐ No No action required.

Done by: ______________________ Date: ______________________

Consider using ground-source heat pumps for condensers instead of cooling-tower water.

Can ground-source heat pump be used to condense refrigerant instead of cooling-tower water?

☐ Yes Hire an engineering consultant to evaluate use of a ground-source heat pump.
☐ No No action required.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.10 Water and compressed air systems

Water systems

A facility may have several water systems, some for process use (process cooling water, chilled water) and some for building services (potable water, domestic hot water). Whatever their function, water systems tend to have similar inefficiencies and energy management opportunities. Water losses are detailed in Table 2.1. The energy cost in operating water systems can be reduced with proper attention to the following areas:

- detecting and eliminating leaks;
- examining water use patterns and reducing water consumption to the minimum necessary;
- imaginative re-use and recirculation of process and cooling waters;
- reduction of friction losses and the associated pressure drops;
- reduction of heat loss from hot water systems and heat gain to chilled water system; and
- correct choice and sizing of pumps and reduction of pump operating time.

Table 2.1
Amount of water lost due to leakage

Leakage rate	Daily loss	Monthly loss	Yearly loss
One drop/second	4 L	129 L	1.6 m^3
Two drops/second	14 L	378 L	4.9 m^3
Drops into stream	91 L	2.6 m^3	31.8 m^3
1.6 mm stream	318 L	9.4 m^3	113.5 m^3
3.2 mm stream	984 L	29.5 m^3	354.0 m^3
4.8 mm stream	1.6 m^3	48.3 m^3	580.0 m^3
6.4 mm stream	3.5 m^3	105.0 m^3	1260.0 m^3

(Note: 1 imperial gallon = 4.546 L; 1 m^3 = 1000 L = 220 imperial gallons)

Knowing the local rates, you can calculate the unnecessary costs above. Chances are that there may be several leaks in a plant at the same time.

Cooling water

A cooling-water system should be designed to recirculate water through the cooling tower or a ground-source heat pump system so that the water can be re-used rather than dumped after a single pass. This will drastically reduce water purchases, treatment costs and the cost of disposal down the sewer. Evaluate the economics of a cooling tower or a ground-source heat pump installation from a long-range perspective. Take into account the costs of electricity to operate fans and pumps, water treatment and make-up water to compensate for evaporation and blowdown, and maintenance.

Tip

Monitor and control the cooling-water temperature so that the minimum quantity of water required to perform the cooling is used.

Consider the alternatives, described more fully in Section 2.7, "Heating and cooling equipment (steam and water)" on page 90. Among them is recovering heat from cooling water for other processes with a heat exchanger or a heat pump.

Hot and chilled water systems

Pipes carrying hot or chilled water should be well insulated to prevent heat loss or heat gain. Chilled-water piping should also have a vapour barrier to prevent condensation from saturating the open-fibre insulation. See Section 2.2, "Process insulation," on page 63.

Other water systems

Water pumps should be shut off when the systems they are serving are not operating. This measure will reduce the electricity costs for pumping and, in the case of cooling water, the cost of water treatment.

Strainers and filters should be checked regularly to ensure that they do not become clogged. Clogged filters cause losses in pipeline pressure. To prevent water losses, inspect pipes frequently and repair leaks promptly; also, reduce evaporation from tanks by installing covers.

Energy management opportunities

Housekeeping EMOs

- Instil good housekeeping practices in all employees, maintain awareness and transform the newly acquired knowledge into habit.
- Do not let water run unnecessarily (taps, hoses, eyewash fountains, drinking fountains, etc.).
- Check and adjust as necessary the appropriate water heating set points, aiming at the minimum required temperature levels.
- Prevent or minimize (particularly hot) water tank overflow occurrences.
- Maintain proper control over water treatment to ensure that design flows are maintained.
- Maintain properly monitoring and control equipment.

Low-cost EMOs

- Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones, equipment and crews with either inconsistent or inefficient performance to correct deficiencies and to set progressively tighter consumption targets.
- Review the areas where high-volume, low-pressure rinsing or flushing makes sense (e.g. at the bottle filler) and where the use of low-volume, high-pressure water flow (nozzles) is called for.
- Identify all hoses and ensure that the smallest diameter necessary is used for the task.
- Fit hoses with automatic cut-off valves (guns) where appropriate.

Tip

As the first step in setting up water system energy management, review current operation practices. Develop a mass and heat balance diagram of water use in different areas of the plant to prepare a water and energy conservation program.

- Re-use all rinse water from cleaning operations, with due regard to product quality implications, wherever possible (for example, during the cleaning-in-place last rinse).
- Collect uncontaminated cooling water for re-use.
- Install adequate holding tanks to suit the requirements of a water re-use system.
- Install water system expansion tanks to serve two purposes. When the water is hot, wastage through relief valves will be prevented. When the water is cold, the contracted volume would demand make-up water to keep the system filled.
- Ensure that hot and cold pipes and water systems are properly and adequately insulated.
- Install flow regulators for sanitary uses: delayed closing/timed flow taps on hand washbasins in restrooms and reduced-flow shower heads.
- Reduce water leakage/waste by bringing the water pressure down in areas where high pressure is not needed.

Retrofit EMOs

- Segregate the hot water system according to the various temperature requirements to reduce unnecessary tampering. Consider setting up a system where discrete hot water boilers feed loads of similar temperature so that the highest temperature does not dictate all loads.
- Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones that have equipment and either inconsistent or inefficient performance to correct deficiencies and to set progressively tighter consumption targets.
- Can a once-through system be converted to a circulating system? Revise the water distribution system to incorporate multiple re-use (recirculation) of process water wherever possible, employing suitable heat recovery regimes, and implement the measures.
- Make water management part of a computer-monitored and controlled system of overall brewery utilities management.
- Review pump sizing, water pressure requirements and delivery distances versus the piping diameter. Often, smaller pumps but larger diameter piping to reduce friction losses provide for more energy efficiency and make better economic sense when all costs are considered.
- Streamline piping systems. Remove redundant, unused branches.
- Upgrade pumps. See Section 2.11, "Fans and pumps," on page 124.

Tip

Consider replacing old hot water boilers with high-efficiency units.

Tip

Calculate annual heat (energy) loss in warm or hot waste water streams being sewered. Consider options for heat recovery.

Compressed air systems

Leaks of compressed air are the most common and major cause of inefficiency, typically accounting for about 70 percent of the total wastage. The cost of inefficiently produced and distributed air may reach $1.00/kWh! Energy losses in a poorly maintained air system arise from the additional energy needed to overcome equipment inefficiencies since the air may not be delivered at the correct pressure.

> Compressed air is the most expensive utility in a plant!

Long-term cost of compressed air generation is typically 75 percent electricity, 15 percent capital and 10 percent maintenance. Simple, cost-effective measures can save 30 percent of generating electric power costs. Consequently, the effort to make a compressed air system energy efficient is highly profitable.

The work should include a thorough audit of the compressed air system (i.e. examinations of compressed air generation, treatment, control, distribution, end use and management). The costs of operating a compressed air system can be reduced in several ways, as described in the following.

Energy management opportunities

Housekeeping EMOs

- Commit to a plant-wide awareness program about compressed air management and energy efficiency.
- Shut off compressed air delivery when not required.
- Avoid the expensive and wasteful practice of using compressed air for cleaning ("dusting off") and cooling duties.
- Prevent leaks in the distribution system. Losses usually occur at joints, valves, fittings and hose connections. Table 2.2 (page 119) shows the amount of air leakage and monthly cost for air leaks of different sizes.
- Generate compressed air at the lowest pressure suitable for the task; never generate at too high a pressure only to reduce it to a lower operating pressure later. Higher pressures are often used to compensate for poor air tool maintenance or undersized air lines.
- Check that the system is not faulty (it requires higher than design pressure).
- Maintain air filters.
- Implement regular maintenance, inspection and preventive maintenance programs of the system as well as of the control and monitoring equipment.

TABLE 2.2
Typical compressed air leakage

Hole diameter	Air leakage at 600 kPa (gauge)	Cost per month at 5¢/kWh
1 mm	0.8 L/s	$9
3 mm	7.2 L/s	$81
5 mm	20.0 L/s	$225
10 mm	80.0 L/s	$900

Low-cost EMOs

- Institute compressed air management, parts of which are
  - instituting metering of the usage by end-point users;
  - instituting user's fiscal accountability for the compressed air usage; and
  - requiring the users to justify the compressed air use.
- Eliminate items such as hoses and couplings on air systems wherever practical in order to reduce the possibility of leakage.
- Ensure proper maintenance program for the compressed air-using equipment as well (proper lubrication, etc.).
- Check that there are no problems with piping that might cause system pressure drops, particularly if the system is to be expanded.
- Use intake air from the coolest location, possibly by direct ducting of fresh intake air from the outside.
- In air-cooled compressors, discharge the cooling air outdoors during the summer and use it indoors for space heating during the winter.
- Ensure that the system is dry: correct slopes of the piping, drainage points, and take-off points (always on top of piping). Beware of piping corrosion; it increases internal piping resistance and can lead to pitting and leaks. In winter, it may cause equipment freeze-ups.
- Remove obsolete compressed air piping to eliminate air losses, leak repair costs and other ongoing maintenance costs.
- Switch off compressors when production is down. If compressed air is needed for instrumentation, install a separate compressor for this function; it will save wear on the main compressors as well.
- When reciprocating compressors and screw compressors are used in parallel, always maintain screw compressors at full load. When partial loads are required, use the reciprocating compressor and shut down the screw compressor.
- Minimize the air dryer regeneration cycle by installing a controller based on dew point measurement.
- Enclose compressors (if applicable) to prevent heat infiltration into buildings if not desired.

Review all operations where compressed air power is being used and develop a list of alternative methods.

Tip

Avoid using compressed air where low-pressure blower air will do the job as well.

Tip

Consider using large-diameter distribution network piping that could double as compressed air storage to reduce friction losses, avoid pressure fluctuations in the system, serve a sudden demand and avoid the need for the compressor to operate continuously loaded. The improved pressure regulation may allow for the overall system pressure to be reduced.

- If compressors are water-cooled, look for ways to recover heat from the cooling water circuit and/or for recycling the water for use elsewhere.
- Make piping changes necessary to shut off production areas where and when there is no demand (off shifts, weekends).
- Minimize the system's constant losses through minor leaks and continuous consumption of various pieces of measuring equipment by fitting section valves.

Retrofit EMOs

- Consider improving the efficiency of the total system by integrating independent compressed air generating/distributing circuits where possible.
- Consider installing an intelligent control system to control air compression installations and to achieve about 10 percent energy savings by maintaining the compressor's output pressure at the lowest possible level and minimum idle running time.
- Evaluate installation of a combustion engine-driven compressor unit as it provides a less expensive energy input and has a better part-load efficiency than electrical motors. It also affords heat recovery from the engine jacket and exhaust.
- Upgrade the compressed air dryer for an energy-efficient version (energy savings of up to 85 percent may be possible).
- On older compressors, consider installing a generously sized buffer tank to improve compressor loading.
- In large facilities, consider installing an automatic leak-measuring scheme run by a central control, regulation and monitoring system.
- Consider installing an airtight plastic pipe distribution network to replace old steel pipe and corroded and leaking circuits, particularly for buried installations. This served one large user in Winnipeg, Manitoba, very well.

Environmental considerations

Operating water and compressed air systems at peak efficiency reduces electrical consumption and thus pollutant emissions from thermo-electricity-generating stations. For information on how reducing electricity consumption reduces pollution and for instructions for calculating reductions, see Section 1.1, "Climate change," on page 1.

More detailed information

Although it was published in the 1980s, the technical manual *Water and Compressed Air Systems* (Cat. No. M91-6/12E), available from NRCan, remains a good reference. See page vi of the preface of this Guide for ordering information.

Water and compressed air systems evaluation worksheet

Water systems: Hot water

Inspect insulation on all hot water pipes.

Is all piping insulated?

☐ Yes Check every six months.

☐ No Install insulation as soon as possible.

Done by: ____________________ Date: ____________________

Is all insulation dry and intact?

☐ Yes Check regularly to maintain standard.

☐ No As soon as possible, find and eliminate sources of moisture and replace insulation.

Done by: ____________________ Date: ____________________

Check water temperature.

Can water temperature be reduced without affecting users?

☐ Yes Reduce water temperature to the lowest level that does not compromise the process it serves.

☐ No Evaluate again when processes change.

Done by: ____________________ Date: ____________________

Water systems: Cooling water

Examine the operation of cooling-water systems.

Does cooling water pass through the equipment more than once before being discharged to the sewer?

☐ Yes No action required.

☐ No Consider using well water for cooling or recirculating the water through a cooling tower.

Done by: ____________________ Date: ____________________

Does cooling water circulate when equipment is idle?

☐ Yes Shut off cooling water supply to idle equipment.

Consider installing an interlock to shut off cooling water automatically.

☐ No No action required.

Done by: ____________________ Date: ____________________

Could the flow of cooling water be reduced without compromising the process?

☐ Yes Reduce the flow of cooling water to the lowest level that will provide adequate cooling.

☐ No No action required.

Done by: ______________________ Date: ______________________

Water systems: General

Inspect all strainers and filters in the water system.

Are strainers and filters clean?

☐ Yes Check regularly to maintain standard.

☐ No Clean or replace partially or totally clogged strainers and filters to prevent pipe pressure losses.

Done by: ______________________ Date: ______________________

Inspect heated tanks, noting thickness of insulation and number of open tanks.

Are heated tanks insulated?

☐ Yes Check that insulation is adequate (cool to the touch).

☐ No Apply an economic thickness of insulation (refer to the technical manual *Process Insulation*, Cat. No. M91-6/1E, available from NRCan).

Done by: ______________________ Date: ______________________

Are heated process tanks covered?

☐ Yes No action required.

☐ No To reduce evaporation, consider installing covers or covering the water surface with plastic balls.

Done by: ______________________ Date: ______________________

Inspect pipes and equipment for leaks.

Do you find any leaks?

☐ Yes Repair leaks as soon as possible.

☐ No Check regularly to maintain standard.

Done by: ______________________ Date: ______________________

Compressed air systems: Air distribution and use

Inspect pipes, hoses, connections and fittings for leaks (best done after the end of a shift).

Are there any leaks?

☐ Yes Repair leaks as soon as possible (using Table 2.2 on page 119, calculate the cost of lost compressed air).

☐ No Check regularly to maintain standard.

Done by: ______________________ Date: ____________________

Conduct a general inspection of the entire compressed air system.

Is compressed air required after the work shift is over?

☐ Yes If only instrument air is required, use a separate, smaller compressor to supply it and shut off the plant air compressor.

☐ No Shut off plant air compressor at the end of the work shift.

Done by: ______________________ Date: ____________________

Is compressed air supplied to areas of the plant where it is not used?

☐ Yes Disconnect air service in those areas (leaks are more likely to go unnoticed in low-use areas, such as storage areas and warehouses).

☐ No No action required.

Done by: ______________________ Date: ____________________

Are air filters clean?

☐ Yes Check regularly to maintain standard.

☐ No Replace clogged filters to reduce losses in system pressure.

Done by: ______________________ Date: ____________________

Equipment operation

Inspect air-using equipment.

Does equipment need repair or maintenance?

☐ Yes To ensure maximum efficiency and minimum use of compressed air, have all air-using equipment maintained and lubricated regularly.

☐ No No action required.

Done by: ______________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.11 Fans and pumps

Motors and drives

Fans provide the motive force to move air against the resistance of an air-conveying system. Pumps serve a similar function, moving liquids against the resistance of a piping system and against changes in elevation. Fans and pumps both use a common element: the electric motor and its drive. The energy efficiency of a system – whether fans, pumps or compressors – can be achieved only when the motor, motor drive and load are all considered as a unit and its components are optimized.

While the power efficiency of an electric motor may be in the 80–90 percent range, high-efficiency electric motors may reach 97 percent.

It is said that up to one half of the potential energy savings in a motor and drive can be achieved through installation improvements, including correct selection and sizing of a motor and its drive, removing/minimizing unnecessary loads and minimizing idling times. This is underlined by proper attention to maintenance.

Replacing obsolete or burned-out motors with high-efficiency units should become the norm. An economical evaluation will certainly be made in each situation. As a general rule, though, when more than half of all electric power in a facility is consumed by electric motors, a retrofit with high-efficiency motors is probably economically justified.

When one takes into account longer equipment lifetime, reduced maintenance and reduced downtime, the return on investment on the VSD becomes much higher.

High-efficiency electrical motors offer many advantages. They

- save energy (i.e. money);
- contribute to reducing consumption of primary energy sources (hence, to reducing greenhouse gas emissions);
- generate less internal heat;
- are cooler and quieter;
- have a longer life because they are more reliable;
- reduce process downtime; and
- reduce maintenance requirements (e.g. bearings replacement).

With VSDs, energy savings of 40 to 60 percent are often possible.

Variable speed drives (VSDs) are relatively recent developments in control electronics. They work as frequency inverters and can regulate, with considerable flexibility, the speed of a motor to fit the process load demand. VSDs are deployed to improve the interaction between the process or equipment and the drive system. See also a note on VSDs under Section 2.4, "Electrical systems" (see page 74).

VSDs offer other benefits besides electric power consumption reduction. They

- enable a wider range in speed, torque and power;
- enable improvements to process flow and control characteristics;
- enable shorter response times;
- reduce noise and vibration levels of the ventilating equipment;
- enable replacing pump systems based on throttling and temperature control;
- contribute to reduction of maintenance and downtime; and
- lengthen the equipment lifetime (e.g. pump wear).

Fans

Centrifugal fans are most commonly used for industrial air handling and HVAC applications. All centrifugal fans operate according to laws related to performance variables, as follows:

- Airflow varies in proportion to fan speed.
- Total differential pressure is proportional to the square of fan speed.
- Power requirement is proportional to the cube of fan speed.

The fan laws show that changes in airflow and resistance to airflow can significantly affect the amount of power required by the fan. This highlights the importance of ducting that does not restrict airflow.

Energy consumption by fans is influenced by many other variables, some of them related to operating and maintenance tasks. Other factors that affect energy use by fans are related to the air-conveying system in which the fan is installed. Correcting inefficiencies in the air-conveying system can be expensive; however, such measures tend to pay back quickly. (For information on retrofit measures, refer to the technical manual *Fans and Pumps*, Cat. No. M91-6/13E, which includes worked examples.)

The energy consumed by the driving motor represents the total of the energy required by the fan to move air and the energy lost in the fan, the motor and the drive. Therefore, it is desirable to choose high-efficiency fans, drives and motors.

Energy management opportunities

Housekeeping EMOs

- Implement a program of inspection and preventive maintenance to minimize component failures.
- Check and adjust belt drives regularly.
- Clean and lubricate fan components.
- Correct excess noise and vibration.
- Clean or replace air filters regularly.
- Clean ductwork and correct duct and component leaks to reduce energy costs.
- Shut down fans when no longer required.

Low-cost EMOs

- Streamline duct connections for fan air entry and discharge to reduce losses.
- Optimize or reduce fan speed to suit optimum system airflow, with balancing dampers in their maximum open positions for balanced air distribution.

Retrofit EMOs

- Add a variable speed motor to add flexibility to the fan's performance in line with changing requirements.
- Replace outdated units with more efficient equipment, correctly sized.
- Replace oversized motors with high-efficiency motors, correctly sized.
- Where a central system must satisfy the requirements of the most demanding sub-system, consider decentralizing the major system into local sub-systems, each serving its own unique requirements.
- Consider controlling the local ventilation system with ultrasonic occupancy sensors; it saved one manufacturer 50 percent of operating costs.

Pumps

Pumps belong to one of two types, depending on their operating principle:

- centrifugal or dynamic pumps, which move liquids by adding kinetic energy to the liquid; and
- positive displacement pumps, which provide a constant volumetric flow for a given pump speed by trapping liquid in cavities in the pump and moving it to the pump outlet.

Pump operation resembles fan operation in that both devices move a substance through a distribution network to an end user. See Figure 2.7 (page 127) for options on energy-efficient pumps. Both pumps and fans, and their drives, must be large enough to overcome the resistance imposed by the distribution system. However, the size of a pump must also take into account the difference in elevation between the pump and the end user, which influences the power requirement of the pump significantly.

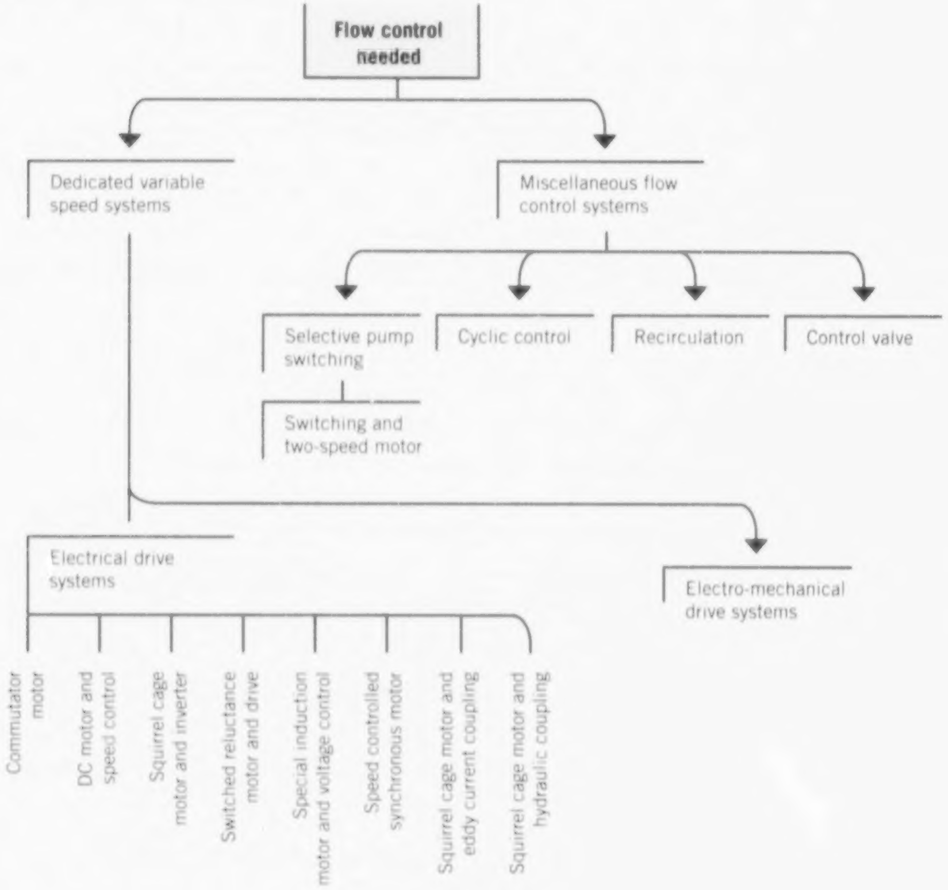
As in fan systems, the cost of energy to operate a pump system can be reduced by installing high-efficiency pumps, motors and drives.

Pump seals

The type of shaft seals installed on a pump and the quality of maintenance performed on the seals can have a significant effect on energy consumption. The two most common types of seals are mechanical and packing-gland seals. Both increase shaft friction and, hence, the amount of power the pump requires; however, the increase in power requirement imposed by packing-gland seals is, on average, *six times greater* than that imposed by mechanical seals.

Figure 2.7

Options for energy-efficient pump operation


Flow control needed
Dedicated variable speed systems
Miscellaneous flow control systems
Selective pump switching
Cyclic control
Recirculation
Control valve
Switching and two-speed motor
Electrical drive systems
Electro-mechanical drive systems
Commutator motor
DC motor and speed control
Squirrel cage motor and inverter
Switched reluctance motor and drive
Special induction motor and voltage control
Speed controlled synchronous motor
Squirrel cage motor and eddy current coupling
Squirrel cage motor and hydraulic coupling

Flow control

Pumps should be carefully sized to suit the flow requirements. If a review shows that a pump is capable of producing more flow or head than the process requires, consider the following measures:

- In applications where the flow is constant, reduce the size of the impeller on a centrifugal pump, if possible. This usually permits use of a smaller motor.
- Install a variable speed drive on pumps where the load fluctuates.
- Optimize pump impellers (change-out) to ensure that the duty point is within the optimum zone on the pump curve.
- Maintain pumps through regular inspection and maintenance to monitor performance for an early indication of failure.

Other energy management opportunities

Housekeeping EMOs

- Shut down pumps when they are not required.
- Ensure that packing glands on pumps are correctly adjusted.
- Maintain clearance tolerances at pump impellers and seals.
- Check and adjust the motor driver regularly for belt tension and coupling alignment.
- Clean pump impellers and repair or replace if eroded or pitted.
- Implement a program of regular inspection and preventive maintenance to minimize pump component failures.

Low-cost EMOs

- Replace packing gland seals with mechanical seals (see preceding).
- Trim the pump impeller to match system flow rate and head requirements.

Retrofit EMOs

- Install a variable speed drive to address demand for liquid flow with flexibility.
- Replace outdated/unsuitable equipment with correctly sized new units.
- Replace oversized motors.
- Consider installing a computerized energy management control system.
- Consider installing variable voltage, variable frequency inverters to allow motor speed to be continuously varied to meet load demand (power savings range from 30 to 60 percent).

Environmental considerations

Measures taken to reduce electricity consumption by fans and pumps help reduce emissions from thermo-electricity-generating stations. For information about reduction of emissions and for instructions for calculating reductions, see Section 1.1, "Climate change," on page 1.

More detailed information

Although it was published in the 1980s, the technical manual *Fans and Pumps* (Cat. No. M91-6/13E, available from NRCan) remains useful. See page vi of the preface of this Guide for information on ordering.

Fans and pumps evaluation worksheet

Operating and maintenance

Inspect the mechanical drives on all fans and pumps.

Are drive belts in good condition and adjusted to the correct tension?

☐ Yes Check regularly to maintain standard.
☐ No Replace worn belts, using matched sets in multiple-belt drives; adjust tension correctly.

Done by: ______________________ Date: ______________________

Do fans or pumps produce excessive vibration or noise?

☐ Yes Locate and correct the problem as soon as possible.
☐ No Check regularly to maintain standard.

Done by: ______________________ Date: ______________________

Inspect all air filters.

Are air filters clean?

☐ Yes Check regularly to maintain standard.
☐ No Clean or replace clogged filters as soon as possible.

Done by: ______________________ Date: ______________________

Inspect the conveying system.

Are there any design flaws, such as bottlenecks that restrict flow?

☐ Yes Consider bringing in a consultant to evaluate the system.
☐ No No action required.

Done by: ______________________ Date: ______________________

Review flow requirements.

Do flows vary?

☐ Yes If flow rates vary consistently, consider using variable speed drives or two-speed motors.
☐ No If flow rates are consistently lower than the rated capacity of your equipment, consider using lower-capacity equipment.

Done by: ______________________ Date: ______________________

Pump seals

Inspect all pump seals.

Do seals leak excessively?

☐ Yes Replace leaking seals as soon as possible.

☐ No Check regularly to maintain standard.

Done by: ______________ Date: ______________

Are any pumps fitted with packing-gland seals?

☐ Yes Consider replacing these pumps with new units with mechanical seals.

☐ No Inspect seals frequently for leaks.

Done by: ______________ Date: ______________

Drives

Identify the types of drives installed on large fans and pumps and find their typical efficiencies.

Are drive efficiencies excessively low?

☐ Yes Consider replacing low-efficiency drives with new, higher efficiency equipment.

☐ No No action required; however, watch for equipment improvements and update drives when it makes economic sense to do so.

Done by: ______________ Date: ______________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.12 Compressors and turbines

Compressors

Section 2.10 dealt with water and compressed air systems, mainly from the distribution system and end-use viewpoints. This section will look at the generating equipment. Compressors are widely used in industrial settings to supply motive power for tools and equipment and, in controls, as the source of air for transmitting signals and actuating valves and other devices. Like steam, water and electricity, compressed air is a plant utility that is easily wasted if certain basic precautions are not taken, such as the following:

- Use as little compressed air as possible.
- Use compressed air at the lowest functional pressure.
- Maintain compressors at maximum efficiency.

The energy consumed by the driving motor of a compressor represents the total power required by the compressor to compress the air or gas, plus energy losses from the compressor, drive and driver. Therefore, it is desirable to select the compressors, drives and driving motors with the highest energy efficiency to obtain the most efficiently operating whole.

Reduce compressed air consumption

Reducing consumption of compressed air reduces the amount of energy required to run the compressor. This is accomplished by maintenance measures such as promptly repairing leaks in the distribution system and by ensuring that compressors and compressed air equipment are shut off when not in use.

Reduce pressure in the compressed air system

Since the power required by the compressor is directly proportional to the operating pressure, operating at the lowest pressure needed to satisfy system requirements can reduce energy costs.

Energy management opportunities

Housekeeping EMOs

The following operating and maintenance items should be reviewed regularly to ensure that compressors are operating at maximum efficiency:

- Inspect and clean compressor air-intake filters regularly to maintain the lowest resistance (pressure drop) possible and reduce the compressor's energy use.
- Ensure that the compressor is supplied with the coolest intake air possible.
- Check the operation of compressed air system coolers – maintain cleanliness of heat-transfer surfaces on both air- and water-cooled compressors to ensure that they do not run hot.
- Monitor the compressor plant's coefficient of performance (COP) regularly and correct deviations from the standard.

Tip

Implement a program of regular inspections and preventive maintenance to minimize compressor component failures.

- Maintain mechanical adjustments – ensure that drive belts are kept at the correct tension, that sheaves and couplings are aligned (correct vibrations), and that drive components are properly maintained and lubricated.
- In multiple-compressor installations, schedule the use of the machines to suit the demand, and sequence the machines so that one or more compressors are shut off rather than having several operating at part-load when the demand is less than full capacity.

Low-cost EMOs

- Modify or relocate air intakes to cooler locations.
- Modify or replace outdated components with high-efficiency units (e.g. lower-resistance air intake filters, larger-diameter piping).
- Install flow-control devices on cooling system heat exchangers to provide stable operating temperatures and prevent excess water flow.
- Invest in a leak detector or air leak tester to measure total volumetric leakage throughout the compressed air system and the compressor capacity.

Retrofit EMOs

Other efficiency improvement measures for compressors involve capital expenditures, and most of these require a detailed analysis by specialists.

- Replace energy-inefficient units such as single-stage air compressors with higher efficiency two-stage compressors.
- Review the compressor plant in use, the type and output of the compressors and the structure of the end-use demand, and consider upgrading them to the most energy-efficient units. This may include a mix of smaller and larger compressors of different types fitted with variable speed drives.
- Consider the economics of decentralizing a major compressed air distribution system that supplies air at the highest pressure required and instead using a sub-system with multiple compressors located near the end-use points, which may have lower pressure requirements.
- If only low-pressure air is needed, replace air compressors with pressure blowers.
- Install variable speed controls on compressors to optimize energy consumption.
- Use a large-capacity air receiver or install large-diameter distribution piping in part of the system to serve the same purpose so as to improve air compressor efficiency under fluctuating loads.
- Recover heat from compressor inter-cooler and after-cooler systems and use the heat elsewhere in the facility.
- Consider installing air-cooled compressed air after-coolers in series with water-cooled units to reduce cooling water consumption and assist the plant heating system.
- Where required, enclose the compressor to trap and exhaust unwanted hot or moist air directly outdoors.
- Review and upgrade compressor control (particularly the unloading systems) for situations when its full output is not required.
- In large facilities with massive compressed air requirements and large compressor plants, consider outsourcing the production of compressed air, as some large organizations have done profitably, with attendant energy savings.

Tip

Use a pressure switch or time clock to shut down the compressor automatically when there is no demand for compressed air.

Tip

Integrate air compressor control within a computerized energy management control system of the facility.

Tip

In large facilities, consider installing an automatic leak-measuring scheme run by a central control, regulation and monitoring system.

Turbines

For many years, steam turbines have been used instead of electric motors; in plants with suitable supplies of high-pressure steam, steam turbines are significantly less expensive to run than large electric motors.

As in a compressor system, the energy consumed by a turbine represents the total power required by the driven equipment (e.g. a generator) and the energy losses from the driven equipment, the drive and the turbine. Therefore, it is desirable to select high-efficiency turbines, drives and driven equipment.

Gas turbines are used in applications that require their particular operating characteristics:

- small size with a high power-to-weight ratio;
- no requirement for external cooling;
- low requirement for maintenance;
- low failure rate; and
- relatively clean emissions.

Operating and maintenance

Well-maintained, correctly operated steam and gas turbines generally improve the energy efficiency and reduce energy costs. Operating and maintenance improvements usually cost little or nothing.

The efficiency of gas turbine operation is influenced by the installation altitude, inlet air temperature and pressure and outlet pressure, as shown in the following. Although little can be done about altitude, the other factors can be affected by ancillary equipment such as intake filters, silencers and waste heat boilers.

- Inlet temperature – each 10 K rise will decrease power output (PO) by 9 percent.
- Inlet pressure – each 10 Pa drop will reduce PO by 0.2 percent.
- Outlet pressure – each 10 Pa increase will reduce PO by 0.12 percent.
- Altitude – each 100 m increase will reduce PO by 1.15 percent.

A gas turbine can generate more power when the intake air is cold. To improve the performance of a gas turbine installed indoors, simply route the combustion air intake to use outdoor air. In warm conditions, chillers and evaporative coolers can also be effective.

Both gas and steam turbines should be insulated to reduce heat losses and, consequently, the volume and pressure of the steam or combustion gases.

Gas turbines present several opportunities to recover heat for other uses. The hot gas may be used directly for drying and other applications, or a heat recovery boiler may be used to generate steam or hot water.

Energy management opportunities

Housekeeping EMOs

- Shut steam and gas turbines down when conditions are less than optimum – that is, when the turbines must operate at less than 50 percent capacity (gas turbines) or 30 percent capacity (steam turbines).
- Check and maintain turbine clearances at turbine rotating elements and seals to minimize leakage and ensure maximum energy extraction from the steam or gas stream.
- Check and clean or replace air intake filters regularly.
- Regularly check for vibrations.
- Ensure that steam turbines are operated at optimum steam and condensate conditions.
- Ensure that gas turbines are operated at optimum inlet and outlet conditions.
- Ensure that all speed control systems are functioning properly.

Low-cost EMOs

- Modify or relocate air intake to provide cool air to gas turbines.
- Recover the heat produced by the oil cooler on a gas turbine.
- Install optimum insulation on equipment.
- Optimize the system's operation by adding or relocating control components (e.g. temperature and pressure sensors).

Retrofit EMOs

- Preheat gas turbine combustion air with exhaust gas (e.g. with a regenerator).
- Utilize heat from the exhaust of gas turbines.
- Utilize heat from the surface of turbines.
- Modify inlet and outlet pipework to reduce pressure (i.e. flow) losses.
- Upgrade turbine components for improved efficiency.
- Consider installing an active clearance control system to maintain tolerances and improve the heat-rate efficiency by 0.3 to 0.5 percent.
- Install a back pressure turbine to act as a steam pressure reducing device.
- Increase the efficiency and capacity of a steam turbine, for example, by
  - rebuilding the steam turbine to incorporate the latest steam path technology;
  - letting low-pressure steam directly into the turbine; and
  - using a portion of the warm condenser cooling exhaust stream for boiler make-up water rather than cold water from the mains.
- Consider innovative uses of exhaust heat recovery for such purposes as steam generation or absorption refrigeration for sub-cooling.
- Where practicable, consider upgrading the gas turbine system to a full-fledged combined heat and power (CHP) (i.e. cogenerating) plant.

Tip

Optimize turbine controls with the most appropriate control devices and systems.

Environmental considerations

Measures taken to reduce electricity consumed by compressors reduce emissions from thermo-electricity-generating stations, as described earlier. Energy-saving measures that reduce fuel consumption by gas turbines also reduce emissions from the turbine.

Reductions in steam use by steam turbines reduce emissions from the boiler that generates the turbine steam. Refer to Section 1.1, "Climate change," on page 1 for information about calculating emissions reductions.

Stringent NO_x regulations in some countries led to developments of a two-step combustion process in a gas turbine, which reduces the flame temperature and thereby lowers the emissions levels. The net output is unaffected, but substantial energy savings have been achieved because steam injection is unnecessary. In another installation, a gas turbine was fitted with a catalytic apparatus to reduce NO_x emissions, with similar energy savings.

More detailed information

A technical manual, *Compressors and Turbines* (Cat. No. M91-6/14E), is available from NRCan. See page vi of the preface of this Guide for ordering information.

Compressors and turbines evaluation worksheet

Use of compressed air

Tour the facility when it is not occupied.

Is there audible hissing of compressed air leaks?

☐ Yes Repair leaks as soon as possible.
☐ No Check regularly to maintain standard.

Done by: ____________________ Date: ____________________

Is unneeded air-using equipment turned off?

☐ Yes Check regularly.
☐ No Shut off unneeded air-using equipment.

Done by: ____________________ Date: ____________________

Are unneeded compressors running?

☐ Yes Shut off unneeded air compressors.
☐ No Check regularly.

Done by: ____________________ Date: ____________________

Review compressed air requirements.

Is the system pressure higher than necessary?

☐ Yes Check the maximum air pressure required in the facility and reduce system pressure, if possible.
☐ No Check regularly to maintain standard.

Done by: ____________________ Date: ____________________

Compressor efficiency

Review compressor maintenance procedures and schedules.

Is the intake air as cool as possible?

☐ Yes No action required.
☐ No Consider ducting cool outside air to the compressor intake.

Done by: ____________________ Date: ____________________

Inspect compressor drives and cooling systems.

Are drive belts in good condition, correctly aligned and set at the correct tension?

☐ Yes Check regularly to maintain standard.
☐ No Replace worn belts.
Align sheaves on all drives.

Done by: ____________________ Date: ____________________

Are cooling system heat-transfer surfaces clean?

☐ Yes Check regularly to maintain standard.
☐ No Clean heat-transfer surfaces as soon as possible.
Add cleaning to scheduled maintenance.

Done by: ____________________ Date: ____________________

Are intake air filters clean?

☐ Yes Check regularly to maintain standard.
☐ No . Clean or replace intake air filters.
Add cleaning to scheduled maintenance.

Done by: ____________________ Date: ____________________

Compressor retrofits

Compare air pressure requirements with the pressure supplied by the compressor.

Does some equipment require only low-pressure air (i.e. 10 psig or less)?

☐ Yes Consider replacing the compressor with a pressure blower.
☐ No No action required.

Done by: ______________________ Date: ______________________

Review compressed air demand.

Does the demand for compressed air vary widely throughout the day?

☐ Yes Consider installing variable speed controls on the compressor drive.
☐ No No action required.

Done by: ______________________ Date: ______________________

Are there many short-term variations in demand?

☐ Yes Install an air receiver to help the compressor operate at maximum efficiency under fluctuating loads.
☐ No No action required.

Done by: ______________________ Date: ______________________

Review drive efficiency.

Is the efficiency of the drive excessively low?

☐ Yes Consult drive manufacturers about replacing it with a high-efficiency drive.
☐ No No action required.

Done by: ______________________ Date: ______________________

Turbines: Operating conditions

Review steam turbine inlet and outlet conditions.

Do inlet and outlet conditions match design specifications?

☐ Yes Check regularly to maintain standard.

☐ No Determine and correct the difference.

Done by: ____________________ Date: ____________________

Review turbine loads.

Do turbine drives operate at less than 50 percent capacity (gas) or 30 percent capacity (steam)?

☐ Yes Shut down the turbine drive.

☐ No No action required.

Done by: ____________________ Date: ____________________

Turbine retrofits

Review drive efficiency.

Is the efficiency of the drive excessively low?

☐ Yes Consult drive manufacturers about high-efficiency drives.

☐ No No action required.

Done by: ____________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.13 Measuring, metering and monitoring

These truisms are worth repeating:

- Measurement is the first step that leads to control and improvement.
- If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it.
- A measurement has real meaning only if it is compared to a standard.

For measurement to be meaningful, it must be combined with monitoring. Measuring, metering and monitoring various flows of energy and materials in a facility are essential for reducing energy use. These functions have the following benefits:

- producing process information, such as temperature, pressure and quantity;
- determining energy performance for comparison when evaluating the progress of energy projects;
- setting up new standards of performance and operational targets;
- day-to-day management and correction of unacceptable performance (i.e. achievement of consistency of operations);
- exposing the misuse of energy;
- facilitation of decision-making related to improving operations;
- planning future energy management initiatives;
- communication of progress made in energy-efficiency performance – stimulating involvement and boosting energy awareness among employees;
- justification of new plant and equipment purchases and/or modifications; and
- integration of the data output into a computerized energy management system in the facility.

Metering of energy-consuming equipment should be a priority so that operators can keep equipment running at peak efficiency and can detect diminishing efficiency. The measurements most useful for monitoring energy use are flow, temperature, humidity, calorific value, enthalpy and electrical quantities such as voltage and current. These variables should be measured at the point of supply to a plant area or a single large energy user, thus permitting observation and recording of energy-use patterns that will allow managers to target energy inefficiencies directly. Energy management requires data that are reliable and accurate.

Accuracy

It is important to know how measurement accuracy is expressed so that the measuring instruments can be matched to process requirements. The common measurement terms are described as follows:

- Measured variable – the variable the instrument was selected to measure, such as temperature or pressure.
- Lower range value – the minimum measurement of the variable that the instrument can display.
- Upper range value – the maximum measurement of the variable that the instrument can display.
- Range of the instrument – the region between the lower-range value and the upper-range value.

The accuracy of an instrument is expressed in terms of the measured variable and may be expressed as a percentage of

- the range of the instrument;
- the upper range value; or
- the indicated value or range.

Accuracy is often improved by reducing the range, so the range of an instrument should be kept to a minimum that is consistent with the expected variations of the measured variable. However, *repeatability* is often more important than absolute accuracy. System accuracy depends on the accuracy of its components and can be determined only by system calibration.

The integration of measuring and monitoring devices into a computerized management system requires signal amplification and digitalization in an analogue digital converter. Although there are plenty of applications for analogue instruments and basic digital instruments, computer-based instruments (with an embedded computer) provide additional flexibility and power to a system. Digital input is processed by the instrument's computer (e.g. single-chip), and outputs can be obtained through a strip-chart recorder, an oscilloscope or a printer or be displayed on a monitor.

Energy management opportunities

Housekeeping EMOs

- Regular **calibration and maintenance programs** are necessary if instruments are to produce reliable data. With the use of electronics today, many instruments are now self-calibrating, saving time and effort and offering continuous accuracy. However, the supporting system must also be taken care of (e.g. ensuring that the compressed air is free of moisture and dirt and that the line filters are maintained regularly). There is an example of how important this item is – in one Canadian paper mill, an out-of-calibration temperature sensor caused a loss of $56,000 per year.

The management of instrumentation, measuring and testing equipment – which includes applicable test software – is well covered under the broadly used international standards for quality (ISO 9001) and environmental (ISO 14001) management systems. Even facilities that have not yet implemented these standards would be well advised to adopt the principles for sound management of their instrumentation, metering and monitoring equipment.

- **Records.** Measuring, metering and monitoring equipment is not of much use without good record keeping. Record keeping is particularly important to the process of identifying deviations from normal operation and changes in energy efficiency. Important information should be logged at regular intervals, either manually or automatically. Inexpensive electronic data-loggers with many desirable features and capabilities are now available, and collecting and recording data reliably has never been easier.
- **Analysis and follow-up.** For the measuring or monitoring activity to make sense, there must be an analysis of the monitored equipment's performance records (conveniently facilitated by many software packages available on the market) and a follow-up on deviations from optimal state. Sometimes, of course, a suitable period must first pass in order to confirm that the deviation is systemic in order to establish a trend and to confirm the need for a corrective or preventive action. At other times, as in a case of simple process inattention, the follow-up must be prompt.

Low-cost EMOs

- **Acquisition of new measuring and monitoring equipment and instrumentation** with an optimum accuracy. For example, boiler plants and other facilities using combustion processes consume significant quantities of fuel. For these, purchase of an oxygen and combustibles analyser is justifiable because a regularly adjusted boiler combustion system can quickly pay back the equipment cost. Similarly, equipment that detects compressed air leaks is a worthwhile investment. Chances are that it will pay for itself in a short time.

- **Correct installation**. One should not assume that an existing installation is functioning correctly just because it has been in use for years. Often, measuring inaccuracies result from improper installation that must be corrected. Non-intrusive measurement techniques are now available, with correspondingly easier installation requirements.
- **Develop a proper design of instrument-measuring systems**.
- **Detectors of abnormal conditions** (e.g. doors to refrigerated warehouse left ajar; tank overflow level situation).
- **HVAC monitoring sensors**.

Retrofit EMOs

Retrofit opportunities in measuring and monitoring equipment and instrumentation exist in these broad categories (and their combinations):

- replacement of pneumatic controls with direct digital controls;
- a specific process equipment or application (e.g. boiler, peak demand regulation); and
- an upgrade or development of a measuring, monitoring and instrumentation system and/or its integration into an overall computerized energy management system in the facility.

Environmental considerations

Measuring, metering and monitoring equipment helps identify energy wastage – that means inefficient energy-using equipment (and, incidentally, allows better justification for the need for improvements, including capital purchases). By ensuring that equipment is operating at peak efficiency – directly or indirectly – fuel consumption and emissions are minimized. For information about the relationship between energy efficiency and emissions, see Section 1.1, "Climate change," on page 1.

Monitoring and targeting (M&T) methodology, using these tools, helps to manage energy and utilities usage to the same effect.

More detailed information

The technical manual *Measuring, Metering and Monitoring* (Cat. No. M91-6/15E, available from NRCan) was published in the 1980s. It covers pneumatic controls well but is limited in its treatment of electronic controls. See page vi of the preface of this Guide for ordering information.

Measuring, metering and monitoring evaluation worksheet

Extent of instrumentation

Observe the level of instrumentation in the facility.

Are energy supplies to all major energy-using equipment metered?

☐ Yes Calibrate the instruments regularly.

☐ No Consider dividing the overall energy supply system into logical energy accounting centres to facilitate management of and accountability for energy use.

Done by: ______________________ Date: ____________________

Are instruments inspected and calibrated regularly?

☐ Yes No action required.

☐ No Implement a program of regular inspection and calibration.

Done by: ______________________ Date: ____________________

Are the measurements incorporated into a computerized energy management system?

☐ Yes No action required.

☐ No Consider purchasing and installing a system to manage the energy use in the facility.

Done by: ______________________ Date: ____________________

Boiler systems

Inspect boilers for the presence of monitoring equipment (note that, by law, many operating variables must be monitored, with alarms and cut-outs for abnormal conditions).

Are boilers equipped with flue-gas analysers?

☐ Yes Inspect and calibrate them regularly.

☐ No Consider installing them to measure oxygen and combustibles in flue gas.

Done by: ______________________ Date: ____________________

Is the boiler equipped with an economizer?

☐ Yes — Measure the temperature of the feedwater and flue gas entering and leaving the economizer.

Thermometers should be either the recording type or part of the boiler automation system.

☐ No — Consider installing equipment to measure flue-gas and feedwater temperature.

Done by: ______________________ Date: ______________________

Review the extent of data-logging.

Is data-logging equipment widely used?

☐ Yes — No action required.

☐ No — Consider installing more data-logging equipment.

Done by: ______________________ Date: ______________________

Electrical monitoring

Review status of metering.

Are all buildings and major equipment metered?

☐ Yes — Record readings monthly and check against utility bills; follow up with actions to improve the power factor and reduce peak demand, and implement other measures outlined in Section 2.4, "Electrical systems," on page 72. Also consider energy management actions stated earlier in Section 2.1.2, "Monitoring and Targeting" (see page 61).

☐ No — Consider installing kW/kVA and kWh meters to monitor all major energy users.

Done by: ______________________ Date: ______________________

Review the extent of data-logging.

Is data-logging equipment widely used?

☐ Yes — No action required; use the output for energy usage management.

☐ No — Consider installing more data-logging equipment.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.14 Automatic controls

Automatic controls take the data produced by monitoring instruments and use these data to control everything from processing equipment to space heating and cooling systems. Many manufacturing processes that used to be manually controlled are now controlled automatically. This innovation has several benefits:

- immediate correction of unpredictable changes;
- simultaneous adjustment of many functions; and
- highly consistent control.

The benefits realized from the use of automatic controls in process equipment are evident in quality and productivity improvements. When used for energy management applications, automatic controls can reduce energy costs by strictly controlling temperatures and flow rates and by adjusting lighting, motor speeds, and fluid and gas flows as required by the process.

Control equipment

Even a casual stroll by the relevant shelves in a reference library or at a trade show will reveal the enormous progress made in this technology in the last decade and in the vast range of devices available. The following discussion will be, therefore, brief and generic.

Programmable logic controllers

The automatic devices most commonly used in process control are programmable logic controllers (PLCs). A PLC system has three main components:

- Input module: devices such as limit switches, push buttons, pressure switches, sensors, electrodes and even other PLCs provide incoming control signals (digital or analogue) to the input module. The module converts the signal to a level that can be used by the central processing unit (CPU) of the controller. It then electrically isolates it and sends it to the CPU.
- Controller: a programmable memory in the controller that stores instructions for implementing specific functions and converts the inputs into signals that go out of the PLC to the output module.
- Output system: this system takes the CPU's control signal (programmed instructions), isolates it electrically and energizes (or de-energizes) the module's switching device to turn on or off the output field devices (e.g. motor starters, pilot lights and solenoids).

An example of a simple PLC used for energy management is one for an air-supply system. The PLC system controls variables such as temperature, airflow to various zones, humidity, filtering, shut-off of airflow to unoccupied areas and exhaust volume. Larger, more complex applications require more sophisticated PLCs, including ancillary data-entry equipment with trouble-shooting capabilities.

To control critical variables more closely, closed-loop PLCs of various degrees of complexity and configurations use a feedback from field devices. This provides more accurate and more adaptive control.

A PLC can be programmed through a hand-held device or downloaded from a personal computer (PC). Conveniently, a programmer can often be used for developing documentation that describes the system's configuration and operation. Sometimes this step is neglected. Documentation should be added to a user program for many reasons. Especially in energy management situations, the documentation will assist in the following ways:

- Operators will receive system information to understand how the system operates.
- Maintenance personnel will be able to troubleshoot and maintain the system.
- Upgrading decisions will be simplified.
- It will help answer questions, diagnose problems and make system modifications if requirements change.
- It will allow easy reproduction of the system if another installation is needed.

Industrial automation controllers

These devices are a new breed of controllers that do not fit neatly into the PLC or PC classification. They are often used for special application controls such as motion and process control, particularly in complex closed-loop servo controls, such as those in robotic systems.

Direct digital controls

Direct digital control (DDC) systems are generally used in large, complex operations where the operations of many devices must be coordinated. Like PLCs, DDC systems include sensors and output devices. A DDC system, however, has a computer instead of a logic controller. The computer makes DDC systems flexible and capable of managing complex processes because the setpoints can be changed dynamically and remotely. They also permit operators to start and stop specific equipment remotely. Another strength of DDC systems is that they can store, analyse and display data.

PC process control

Individual PLCs can be replaced by fully integrated PC process control packages. The energy manager profits from consistent, repeatable process control that integrates operations. Various packages are available, and their application can assist energy-saving efforts in, for example, the boiler house, refrigeration and packaging. They can be complemented by simulations packaged to test various "if" scenarios. In the integration of the system, various means of electronic signal transmission are employed and may include, for example, radio frequency (RF).

Investment in a process optimizer will reduce the specific energy consumption in a plant through the use of a sampling system and a control computer so that the factory operates with the minimum amount of energy.

Expert computer control systems (also called artificial intelligence systems)

An expert computer control system (ECCS) uses specialized knowledge, usually obtained from a human expert, to perform problem-solving tasks such as diagnosis, advice, analysis and interpretation. By capturing and formalizing human expertise, such systems can

- improve productivity and reduce delivery time;
- improve the quality of advice given or analyses made, thus improving operating efficiency and product quality; and
- make rare expertise readily available, thereby alleviating skills shortages (especially when valued, experienced professionals retire).

ECCSs are not yet used extensively in Canada but are commercially available. They incorporate enhanced computer control to coordinate and optimize process operations with significant energy conservation potential. Examples of applications include heavy industry, refrigeration control and manufacturing controls, especially linked utilities usage. Their deployment within an M&T system puts energy and utilities management on par with the management of any other resource in the plant. For example, one U.K. plant, faced with steadily increasing refrigeration energy costs, installed a refrigeration fault diagnosis expert system, which continually monitors performance, assesses the plant's current performance, suggests possible causes for below-par performance and recommends remedial actions.

Environmental considerations

Automatic controls affect emissions of pollutants indirectly; use of automatic controls can reduce energy consumption by a process or equipment, thus reducing emissions at the point of power generation. See Section 1.1, "Climate change," on page 1 for information about the effect of energy use reductions on emissions and for instructions for calculating reductions.

Automatic controls evaluation worksheet

Systems that can be converted to automatic control

Tour the facility, noting how energy-using operations are controlled.

Are some operations still controlled manually?

☐ Yes Obtain advice from an engineer on installing PLC or DDC systems.

☐ No No action required.

Done by: ____________________ Date: ____________________

Are PLC or DDC systems used?

☐ Yes Calibrate sensors, check controller setpoints and final control devices and verify integrity of programming.

Institute preventive maintenance program.

☐ No Consider suitable applications through a retrofit of control systems.

Done by: ____________________ Date: ____________________

Do you have several PLC-controlled processes that conflict?

☐ Yes Consider replacing them with a DDC system that can supervise and control the entire process.

☐ No No action required.

Done by: ____________________ Date: ____________________

Is there a potential for ECCS installation?

☐ Yes Obtain expert advice on the potential application.

☐ No No action required.

Done by: ____________________ Date: ____________________

Is all process and space heating and cooling equipment controlled with thermostats?

☐ Yes Check controls to ensure that they are working correctly.

☐ No Install (programmable) thermostatic controls on uncontrolled equipment (use setback-type thermostats on space-heating and cooling units where applicable).

Consider integration of controls in a building energy management system.

Done by: ____________________ Date: ____________________

Is outdoor lighting manually controlled?

☐ Yes — Consider installing either photocell controls or timers to ensure that lights are shut off during daylight hours.

Consider installing motion detectors to ensure that lights are on only when needed during the night.

☐ No — Check photocells or timer controls to ensure that they are working correctly.

Done by: ______________________ Date: ______________________

Is indoor lighting manually controlled?

☐ Yes — Consider installing occupancy sensors, timers or both.

☐ No — Check controls to ensure that they are working correctly.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.15 Architectural features

A comprehensive energy management program is not complete until the buildings themselves are evaluated for their impact on overall energy use. Older buildings, erected before 1980, when energy was comparatively cheap, are often inadequately insulated and sealed. Modern building codes set minimum requirements for energy conservation in new buildings. See, for example, the introduction to the *Model National Energy Code for Buildings*, obtainable from the Web site at http://oee.nrcan.gc.ca/english/programs/energycode.cfm. These new requirements also apply in full to repair, renovation or extensions of older buildings. Energy efficiency must be designed to good engineering practice as described in the preceding and in the ASHRAE/IES Standard 90.1-1999 – "Energy efficient design of new buildings."

These and many other regulations and standards that cover industrial buildings' construction and operation (e.g. insulation, heating and ventilation) also ensure that health, safety and occupational comfort requirements are met. In any consideration of building energy efficiency improvements, these aspects must be carefully examined.

The heat lost from a building in winter and gained in summer must be overcome by the HVAC systems, which adds to the cost of operating the facility. Heat loss and gain through the building envelope can be reduced in two major ways:

- reducing heat transfer (gain or loss) through building components (e.g. walls, roof and windows); and
- reducing air leaks – both infiltration and exfiltration – through openings (e.g. doors and windows).

Reducing heat transfer

Walls and roofs

In many buildings, upgrading wall insulation is difficult and expensive because of the original construction technique or because activities inside the building would be disrupted. In such cases, it is often possible to add insulation to the exterior of the building and cover it with new weatherproof cladding. Buildings with large south- or southwest-facing walls can be retrofitted with a type of "solar wall" (see Section 2.8, "Heating, ventilating and air conditioning systems," page 99) for even greater energy efficiency. Industrial buildings that have large, flat roofs benefit particularly from roof insulation upgrades because most of the winter heat loss and summer heat gain occur through the roof. A new, insulated roof membrane can be covered with heat-reflecting silver-coloured polymeric paint to help minimize the heat transmission. See Table 2.3 on page 152 for information on thermal resistance. Good construction practices must be observed, such as provision for ventilation of ceiling and roof cavities and prevention of water vapour from entering the insulated cavity as specified in building codes.

TABLE 2.3
Minimum thermal resistance of insulation

	RSI (R) value required		
Building element exposed to the exterior or unheated space	**Zone 1 < 5000 degree-days**	**Zone 2 > 5000 degree-days**	**Electric space heating Zones 1 and 2**
Ceiling below attic or roof space	5.40 (R-31)	6.70 (R-38)	7.00 (R-40)
Roof assembly without attic or roof space	3.52 (R-20)	3.52 (R-20)	3.87 (R-22)
Wall other than foundation wall	3.00 (R-17)	3.87 (R-22)	4.70 (R-27)
Foundation wall enclosing heated space	1.41 (R-8)	2.11 (R-12)	3.25 (R-19)
Floor other than slab-on-ground	4.40 (R-25)	4.40 (R-25)	4.40 (R-25)
Slab-on-ground containing pipes or heating ducts	1.76 (R-10)	1.76 (R-10)	1.76 (R-10)
Slab-on-ground not containing pipes or heating ducts	1.41 (R-8)	1.41 (R-8)	1.41 (R-8)

Based on degree-day zones. See your local building permit office for guidance.

Source: *Ontario Building Code*, 1997.

Windows

Many older buildings, especially factories, have single-glazed, inadequately sealed windows. Short of replacing them with modern sealed-glass windows, plastic or glass-fibre window panels can be used. Some panels are manufactured as double-glazed units that allow the passage of light but are unbreakable and more energy efficient than single-glazed glass windows. See Table 2.4 on page 153 for some details on insulation values.

In the past decade, there have been many improvements in window technology over the typical double glazing with an air space width of 12 mm, which gives an insulation value of RSI 0.35 (R-2).

- Standard triple glazing adds an extra air space (and also weight) and thus insulation.
- Glass coatings reduce heat emissivity and reflection. Low-emissivity (Low-E) coating reduces radiant heat through the glass and achieves about the same insulation as uncoated triple glazing.
- Gas fill – filling the inter-pane space with argon or krypton – further increases the insulation.
- High-performance triple glazing may utilize Low-E as well as gas fill. The insulating value is almost five times as great as that of a single-paned window.

First seal the building to prevent air infiltration and exfiltration and **then** look at your insulation and HVAC system.

TABLE 2.4
RSI/R insulation values for windows

Glazing layers	Glazing type	RSI/R value
Double – one air space of 12 mm	Conventional, air	RSI 0.35 / R-2
	Low-E	RSI 0.52 / R-2.9
	Low-E with argon gas fill	RSI 0.62 / R-3.5
Triple – two air spaces of 12 mm	Conventional, air	RSI 0.54 / R-3
	Low-E	RSI 0.69 / R-3.9
	Low-E with argon gas fill	RSI 0.76 / R-4.3

Windows can also be shaded, curtained inside or shuttered outside to keep out summer heat and winter chill (this is also governed by building codes and ASHRAE regulations).

Reducing air leaks

Examine all openings (vents, windows and outside doors) for cracks that allow air to leak in and out of the building. Block the cracks with caulking or weatherstripping.

Vestibules, revolving doors and automatic door closers all help reduce losses from open doors. Door seals at loading docks should be inspected regularly; worn or damaged seals leave large gaps between the dock and the trailer.

Insulated doors have an RSI value of about 1.2 (R-7), compared with an RSI value of 0.35 (R-2) for a traditional solid wood door. The most energy-efficient door is an unglazed insulated door with double weatherstripping. Refrigerated spaces require special doors.

Energy recovery

Building codes recommend that systems that recover energy should be considered when rejected fluid, including air, is of adequate temperature and a simultaneous need for energy exists for a significant number of operating hours. Recently, many case studies have been posted on the Internet to show that commercial and industrial buildings can reduce energy consumption significantly by applying heat exchangers and heat pumps (including ground-source heat pumps), often achieving savings of greater than 50 percent.

At a minimum, the design and installation of ground- and water-source heat pumps must comply with the requirements of Canadian Standards Association (CSA) standards CAN/CSA C748, C13256-1 and C13256-2.

Tip

- Double glazing is the minimum standard in Ontario.
- Choose improved sealed units for north-facing and highly exposed windows.
- Low-E coatings work best with gas fill.

An average factory door with a 3.2-mm crack has an infiltration rate of 5 L/s per metre length of crack. A poorly installed door with a 6.4-mm crack allows twice as much infiltration. **Reducing the infiltration will save money in heating or air-conditioning costs.**

Central building energy management

Building codes also recommend that a central energy monitoring and control system in a building should, as the minimum, provide readings and retain daily totals for all electric power and demand and for external energy, water and fossil fuel use.

Some facilities must combat the effects of harsh Canadian winters by installing external heating cables to prevent the formation of ice (e.g. in gutters and downpipes, on glass roofs and flat roofs with internal heated downpipes and in parking lots, driveways and entranceways). Often, the power stays on all winter. Elsewhere, manual control tends to be crude and imprecise, increasing energy consumption unnecessarily. An intelligent control system, as part of the central building energy management system, will provide an effective solution.

Other energy management opportunities

In addition to the examples and ideas discussed in the preceding, consider using the following, if applicable:

- a thermography consultant to discover areas that need (additional) insulation or air-leakage control;
- additional insulation as economically feasible, with a long-range view to saving energy costs; and
- innovative use of passive or active solar heating technology for space and/or water heating, especially when combined with improved insulation, window design and heat recovery from vented air.

Environmental considerations

Insulating and sealing a building against winter cold and summer heat reduces the energy required for the heating and cooling systems and thus reduces the pollutant emissions associated with operating these other primary energy generating systems. See Section 1.1, "Climate change," on page 1 for information on quantifying the reduction of emissions due to reduced energy consumption.

Architectural features evaluation worksheet

Wall insulation

Check wall construction, particularly the type and thickness of insulation.

Is the wall adequately insulated? Look for frost or condensation on the inside of outer walls in winter.

☐ Yes No action required.

☐ No Increase insulation by adding a layer either inside or outside the building. Consult an insulation contractor for information about suitable upgrades.

Done by: ____________________ Date: ____________________

Is there a properly installed, adequate water vapour barrier over insulated surfaces?

☐ Yes No action required.

☐ No Install water vapour barrier or vapour-impervious internal wall cladding.

Done by: ____________________ Date: ____________________

Check roof construction, particularly the type and thickness of insulation.

Is the roof adequately insulated? Snow accumulates on a well-insulated roof.

☐ Yes No action required.

☐ No Consider upgrading roof insulation as soon as possible (consult an insulation contractor).

Done by: ____________________ Date: ____________________

Windows

Check windows for type and condition.

Do you have any single-glazed windows?

☐ Yes Replace them with double- or triple-glazed windows or install exterior storm windows (consult a contractor).

☐ No No action required.

Done by: ____________________ Date: ____________________

Are any windows cracked or broken? Are there any gaps between window frames and walls?

☐ Yes Replace cracked and broken windows.
Caulk gaps in and around window frames.

☐ No Check every six months to maintain standard.

Done by: ______________________ Date: ____________________

Do many windows face east, south or west?

☐ Yes To reduce summer heat gain, consider installing reflective glass in the windows or covering them with blinds or curtains.

☐ No No action required.

Done by: ______________________ Date: ____________________

Infiltration and exfiltration of air

Check for leaks around vents, windows and doors, including loading dock doors; check for windows and doors left open unnecessarily.

Did you detect drafts around any vents, windows and doors?

☐ Yes Install weatherstripping on doors.
Caulk vents and windows where the frames meet building walls.

☐ No No action required, provided all is in order; however, consider hiring a weatherizing expert who will depressurize the building to confirm the integrity of your building envelope.

Done by: ______________________ Date: ____________________

Do outside doors have vestibules?

☐ Yes No action required.

☐ No Consider installing vestibules, revolving doors or automatic door closers to minimize the passage of air through outside doors.

Done by: ______________________ Date: ____________________

Do loading dock doors have dock seals?

☐ Yes Check frequently to ensure that they are well maintained.

☐ No Install dock seals to reduce air leakage.
Consider installing air curtains.

Done by: ______________________ Date: ____________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.16 Process furnaces, dryers and kilns

Many facilities contain fired equipment (e.g. furnaces, dryers and kilns) that consumes fuel directly to heat the process, rather than transferring it from a medium such as water or steam. In these units, the heat is applied directly or indirectly from the flame to the process material.

Furnaces, dryers and kilns, which operate at very high temperatures, may offer many heat-recovery and energy-saving opportunities. Before considering heat-recovery options, however, consider the following:

- Examine current practices – is the high heat actually needed?
- Ensure that these systems are operating at maximum efficiency. First, deal with energy losses through excess air, flue-gas temperatures, radiation and conduction.

Here is an example of the first point: A bicycle manufacturer switched from solvent-soluble primer to water-based paint. Apart from obvious environmental benefits, this allowed the manufacturer to lower drying and curing temperatures considerably. The energy consumption of the drying furnace was reduced, too. Integrating a muffling furnace with the drying tunnel of the priming section produced additional savings.

After examining the above points, consider applying one of the many methods available today to minimize energy requirements and extract heat from exhaust air.

Heat losses

Excess air

The amount of excess air used in a furnace, dryer or kiln varies according to the application: for example, a direct-fired drying oven requires large quantities of excess air to remove vapours quickly from it (see the example preceding). Excess air carries heat away from the process and up the stack, so this air should be monitored and adjusted to the minimum quantity necessary to do the job.

Even small (0.16-cm, or $^1/_8$-in.) gaps around doors, etc. quickly add up to a large open area, and substantial amounts of cold air can infiltrate. The excess air takes away from the heat required to heat the product. Savings will result when the excess air is reduced. Proper maintenance can reduce but seldom eliminate cold air infiltration (except in new equipment); instead, use furnace pressurization and burner flame management and control. Maintaining positive pressure at all times inside the furnace will prevent cold air infiltration through leaks. Technologies that regulate the chimney stack opening and a variety of pulse-fired combustion methods, together with maintaining steady heat levels (high fire is on most of the time), can also prevent cold air from entering. Combined energy savings may be as high as 60 percent along with substantial emissions reductions.

FIGURE 2.8

Energy loss from furnace walls versus outside wall temperature

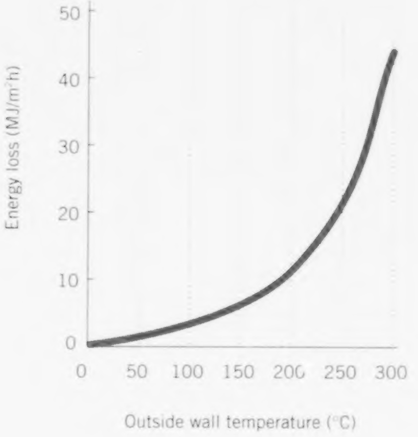
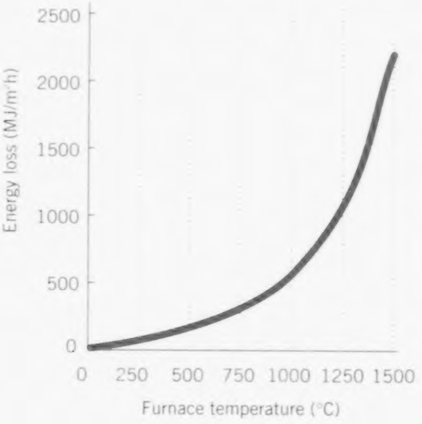


FIGURE 2.9

Energy loss by radiation through opening versus furnace temperature



Radiation and convection heat loss

Heat losses due to radiation and convection from a furnace, dryer or kiln can be high if the enclosure is not properly maintained. Heat loss can occur because of deficiencies such as

- damaged or missing insulation;
- missing furnace doors and covers;
- damaged, warped or loose-fitting furnace doors and covers; and
- openings in the furnace enclosure that allow passage of air.

Figures 2.8 and 2.9 illustrate the relationship between outside furnace wall temperature and energy loss from the furnace walls, and between furnace temperature and energy loss through openings in furnace walls.

Controls and monitoring

Without adequate controls, energy efficiency improvement efforts will fail. Monitoring equipment should be installed so that operators can determine energy consumption per unit of output. They can then identify deviations from this standard and take corrective action.

Furnace efficiency can often be improved by upgrading burner controls and their type, as mentioned above. Automating systems that include fuel and airflow meters, gas pressure control, flue damper control through pressure sensors, and tight in-furnace conditions monitoring for sloping control will permit closer energy consumption control and lower levels of excess air. Systems with oxygen trim allow for even better control of excess air.

In drying or kilning, the meters can measure final moisture content of dried solids, product quality and heat and power input to the equipment.

The controlling and monitoring technologies incorporate proportional integral derivative controllers, feedback and feedforward control, process integration control, dynamic modelling and expert computer control systems.

Generally, the benefits of monitoring and controlling industrial furnaces, ovens and kilns include the following:

- reduced product losses;
- improved product quality and consistency;
- improved operational reliability; and
- energy efficiency improvements of 50 percent or more.

Drying technologies

This section points out briefly the range of technologies currently available for upgrading or retrofitting existing equipment to improve process energy efficiency. To remove water or organic solvents by evaporation, a gas (normally air) is used to transfer the necessary heat to the substrate to be dried in a variety of industrial equipment. The air also carries away the vapour produced. The heating is usually indirect. Drying heat can also be supplied by other means such as dielectric heating (including microwave and radio frequency techniques), electromagnetic induction, infrared radiation, heat conduction through the walls of the dryer and combinations of these methods.

Direct heating

Direct heating incorporates a mixture of hot combustion gases from a burner, recycled air and fresh air. It eliminates the use of heat-transfer equipment in indirect drying. Hence, the conventional heat losses are reduced from about 40 to 50 percent in steam-using systems to 10 percent in direct heating. Employing hot exhaust gases from a gas turbine in a combined heat and power system further improves the overall efficiency. Since natural gas is the most commonly used fuel, products are not contaminated with exhaust gases; direct heating may be used to dry food products.

Direct heating can be cost-effective. It may be included at the process design stage or retrofitted into an existing dryer. The benefits include more precise temperature control, improved uniformity of heating, increased throughput (i.e. reduction of energy use per unit of production) and the possibility of integrating it into an existing control system.

Electric heating

This method aims the heating effect of electromagnetic energy precisely to the solid or to the moisture in the solid, thereby avoiding the need to heat a stream of drying air. Efficiency is 100 percent at the point of use, and the efficiency of generation from AC power is 50 percent for radio frequency and 60 percent for microwave energy. Induction drying can be used only when a substrate is an electrical conductor. The benefits of electric heating include precise control of oven temperatures, improved product quality, short start-up times, simpler maintenance of the ovens and reduced environmental impact from the overall process.

The speed of drying also improves dramatically (e.g. to as little as 3 percent of what a conventional process would take, as in ceramics drying). That fact results in short payback periods of one to three years.

The energy savings derived from installing an electrically heated dryer depend on the energy efficiency of the dryer being replaced.

Other measures

To improve the efficiency of dryers and kilns, supplemental processes can be employed:

- mechanical dewatering, such as with presses;
- desaturation – by gravity draining, centrifuging or use of an air knife to remove surface moisture; and
- thermal insulation to system parts that are not insulated or that have insufficient insulation (e.g. burner compartments, ductworks, heat exchangers).

Using superheated steam as the drying medium eliminates the use of air and allows the evaporated water to be used as a source of heat for other processes. Compared with a conventional dryer, the use of superheated steam results in 20 percent less energy being used. With heat recovery techniques, the energy savings can reach 80 percent.

Heat recovery

Estimate the economics of a heat recovery system for the given dryer by following these steps:

- Determine the input/output air temperatures and humidities.
- Evaluate the quantity of heat recoverable through process integration.
- From the contractor's quotations, derive value for total cost per kWh of heat recovered to estimate the total cost of the project.
- From local prices, determine the value of each saved kWh.
- Derive the simple payback period.

In a dryer installation, heat recovery may apply to the transfer of exhaust heat to the input air (e.g. by a heat exchanger or by mixing part of the recycled exhaust with fresh input air), to the product or to another process stream or operation. Each heat recovery system must be correctly selected for a given application and for the dryer used. Such systems may include heat pumps (electrically or gas engine-driven), exhaust air recycle systems, heat pipes, direct contact heat exchangers, gas-to-gas plate and tubular recuperators, runaround coils and heat wheels. Seek the advice of a knowledgeable and unbiased consultant for the best solution to your particular problem because you may not receive unbiased advice from a vendor.

Furnace and kiln stack temperatures are generally higher than boiler stack temperatures. Higher temperatures provide several opportunities to recover and re-use heat.

The type of heat-reclaim system implemented is driven by how the reclaimed heat will be used. Among the methods for furnace or kiln heat reclaim are heat exchangers (recuperators). They transfer the heat from hot flue gas to combustion air. Regenerative air heaters use two separate sets of refractory bricks, which are alternately heated by the hot flue gas and cooled by the incoming combustion air. In wood-processing plants, which use biomass burners, the heat may also be used to pre-dry the wet bark to be burned.

Another method to improve energy efficiency, particularly in the cement, lime and alumina calcination industries, is with dual fuel burners. These can complement temporary shortages of the primary fuel – carbon monoxide (CO) – with natural gas; plants can therefore avoid energy-wasting kiln shutdowns when CO supply is low, as one large Canadian operator recently demonstrated.

The energy potential of furnace or kiln waste gases, such as CO, can be put to good use in a variety of industries (primary metals, petrochemical, recycling) by recovering the heat from the flares. This heat can be used for boiler combustion air pre-heating or even for micro-turbine generator operation.

Energy management opportunities

These ideas are in addition to the those presented above:

Housekeeping EMOs

- Paying proper attention to the drying equipment and upstream processes can save 10 percent of the total energy load.
- Implement a program of regular inspection and preventive maintenance.
- Maintain proper burner adjustments and monitor flue gas combustibles and oxygen.
- Keep heat exchanger surfaces clean.
- Schedule production so that each furnace/kiln or drying oven operates near maximum output.
- Maintain equipment insulation.

Low-cost EMOs

- Upgrade or add monitoring and control equipment.
- Relocate combustion air intake to recover heat from other processes (or from within the building).
- Replace warped, damaged or worn furnace doors and covers.

Retrofit EMOs

- Install an air-to-liquid heat exchanger to heat process liquids such as boiler make-up water (large systems may permit the use of a waste-heat boiler).
- Install a scrubber to recover heat while removing undesirable particles and gases (captured and recycled particulate matter may help reduce raw material cost).
- Examine other types of drying heat delivery (i.e. modern product heating/drying technologies already described), for replacing outdated drying/curing ovens.
- Examine the use of supplementary fuels for kiln furnace operations (e.g. old tires).
- Integrate and automate operational control for optimum energy efficiency.
- Change the method of conveying product through an oven to facilitate rapid heat transfer to the product (e.g. exchanging wagons for open heat-resistant racks/platforms, etc.).

- Optimize electric arc furnace operations by continuously analysing off-gas combustible hydrogen and CO and by linking it with the regulation of burner ratios, oxygen injections and carbon additions.
- In iron foundries, optimize the use of coke oven gas, blast furnace gas and natural gas by optimizing the distribution system capability, automation and computer control, to minimize flare-offs and natural gas purchases.

Environmental considerations

Energy-saving measures that reduce fuel consumption also reduce emissions of carbon dioxide (CO_2) and other pollutants. See Section 1.1, "Climate change," on page 1 for a practical method of calculating emissions reductions resulting from fuel savings.

More detailed information

The technical manual *Process Furnaces, Dryers and Kilns* (Cat. No. M91-6/7E, available from NRCan) offers much more detailed descriptions of opportunities to save energy. See page vi of the preface of this Guide for ordering information.

Process furnaces, dryers and kilns evaluation worksheet

Excess air

Measure flue gas oxygen content and compare with design specifications.

Oxygen content: _____ percent; Excess air: _____ percent

Is the excess air content appropriate for the application?

☐ Yes Check periodically to maintain standard.

☐ No Ask a burner technician to determine whether the burner can be adjusted to operate with less excess air.

Done by: ________________________ Date: ______________________

Condition of enclosure

Inspect the enclosure of the furnace, dryer or kiln, noting missing or damaged insulation, doors and covers.

Have any doors or covers been damaged or removed?

☐ Yes Repair or replace missing or damaged doors and covers.

☐ No Check periodically to maintain standard.

Done by: ________________________ Date: ______________________

Is the insulation intact?

☐ Yes Check frequently to maintain standard.

☐ No Repair or replace missing and damaged insulation.

Done by: ________________________ Date: ______________________

Is the insulation adequate (i.e. is the exterior of the oven cool to the touch)?

☐ Yes Check periodically to maintain standard.

☐ No Add insulation (consult the technical manual *Process Insulation*, Cat. No. M91-6/1E, for information about installing an economic thickness).

Done by: ________________________ Date: ______________________

Controls

Examine the burner controls for options such as flue-gas oxygen sensors, fuel meters and airflow meters.

Is your burner equipped with these options?

☐ Yes If your excess air is too high, your controls need to be adjusted.

☐ No Consider upgrading your burner controls to include oxygen trim and individual fuel and air metering and control.

Done by: ______________________ Date: ______________________

Flue-gas heat recovery

Measure flue-gas temperatures during normal furnace operations.

Temperature: _____°C

Check for economizers or air heaters.

Is the equipment fitted with any heat-recovery devices?

☐ Yes At next shutdown, evaluate
- whether fins and tubes are corroded or otherwise damaged; and
- how much soot has accumulated.

Check that the unit is operating and not bypassed.

Calculate the heat recovered and compare performance with design specifications.

☐ No Contact equipment suppliers to evaluate the feasibility of installing heat-recovery equipment.

Done by: ______________________ Date: ______________________

Use of waste gases in dryers

Investigate the availability and suitability of hot gases from other processes.

Are flue gases from other equipment available at suitable temperatures and in appropriate quantity and flow rate?

☐ Yes Consult specialists to design a system to replace prime fuel with waste gases.

☐ No No action required.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.17 Waste heat recovery

Throughout this Guide, the subject of waste heat recovery has been mentioned, with many specific examples already mentioned. Heat recovery is a complex task, and great advances in developing suitable technologies have been made in recent years. Perhaps no other energy efficiency topic has been reported on more frequently. Research it thoroughly to find the best application for your particular situation.

Waste heat (or surplus heat) recovery is the process of recovering and re-using rejected heat to replace purchased energy. Heat recovery opportunities arise in the process and environmental systems of almost every facility. Recovery and re-use of waste heat can reduce energy costs and improve the profitability of any operation.

Usable energy may be available from

- hot flue gases;
- hot or cold water drained to a sewer;
- exhaust air;
- hot or cold product or waste product;
- cooling water or hydraulic oil;
- ground-source thermal energy;
- heat collected from solar panels;
- superheat and condenser heat rejected from refrigeration equipment; and
- other sources.

Waste heat is rejected heat released from a process at a temperature that is higher than the temperature of the plant air. As it is often available at a temperature that is lower than the intended level, its temperature must be raised, or "upgraded," through the use of suitable equipment.

In contemplating waste heat recovery, take into account the following considerations:

- Compare the supply and demand for heat.
- Determine how easily the waste heat source can be accessed.
- Assess the distance between the source and demand.
- Evaluate the form, quality and condition of the waste heat source.
- Determine whether there are any product quality implications of the waste heat recovery project.
- Determine the temperature gradient and the degree of heat upgrade required.
- Determine any regulatory limitations regarding the potential for product contamination, health and safety.
- Perform suitability and economic comparisons (using both the payback period and annuity method evaluations) on the short-listed heat recovery options.

Tip

Returning the recovered heat to the process from which it came should be the first priority because such systems usually require less control and are less expensive to install.

Heat recovery technologies

The types of technology that are commonly used to recover waste heat and make it available for re-use are the following:

- **Direct usage** and **heat exchangers** make use of the heat "as is."
- **Heat pumps** and **vapour recompression** systems upgrade the heat so that it can perform more useful work than could be achieved at its present temperature.
- **There are multi-stage operations** such as multi-effect evaporation, steam flashing and combinations of the approaches already mentioned

Direct usage

Direct usage involves using the waste heat stream as it is for another purpose. Examples of direct use include using boiler flue gas for drying and using warm exhaust air from a mechanical room to heat an adjacent area. Direct usage techniques require precautions and controls to ensure that the untreated waste stream does not cause harmful effects, such as contaminating the product or endangering health and safety.

Heat exchangers

Heat exchangers and heat pumps have the widest range of applications, regardless of the industry type. Heat exchangers transfer heat from one stream to another without mixing the streams. Heat exchangers belong to one of the following categories, according to use:

- gas-to-gas (plate type, heat-wheel type, concentric tube, metallic radiation recuperator, Z-box, runaround systems, heat pipes, furnace burner heat recuperation);
- gas-to-liquid, liquid-to-gas (finned tube, spiral, waste-heat boilers);
- liquid-to-liquid (plate type, spiral, shell and tube types); and
- fluidized bed (for severely fouling environments, such as in pulp and paper mills).

A vast array of designs suited to varied needs is available. Due consideration should be paid to selecting proper materials to prevent corrosion or fouling; these may include stainless steel, nickel, special alloys, borosilicate glass, ceramics, graphite, polytetrafluoroethylene (PTFE), enamels and polyester for some applications.

The newly released compact heat exchangers (CHEs) are still at the stage of active development but are being greeted enthusiastically. Their volumes are less than half of those of comparable shell-and-tube heat exchangers, they are more versatile, and they allow more energy to be transferred between the streams (sometimes even multiple streams). A CHE also offers the possibility of combining functions with other unit operations, thus changing the process design radically. Through the possibility of combining a CHE with reactors and separators, additional applications of energy efficiency opportunities have arisen in fuel cells, absorption cycle machines, gas turbines and reformers. A CHE achieves high heat transfer coefficient in small volumes, usually through extended surfaces. It offers tighter process control. Other techniques, such as rotation, led to the development of compact heat pumps, separators and reactors, also allowing faster processing – all contributing to making process operations more energy efficient. The sales of CHEs across the entire range of process industry sectors are increasing about 10 times faster than total sales for heat exchangers. Based on a realistic rate of integration of this technology over the next 10 years, the CHE's potential for energy savings is estimated in Europe alone at US$130 million annually.

Heat pumps

Heat pumps enhance the usefulness of a waste energy stream by raising its temperature (a mechanical refrigeration system adds mechanical energy to the stream of recovered heat). A heat pump is most beneficial where heat from a low-temperature waste stream can be upgraded economically. An industry survey in 1999 indicated that heat pumps are one of the least-understood categories of energy efficiency equipment. This may be one reason that this useful method of waste heat recovery (and of heat dissipation!) is not as widespread as it deserves to be. It is true that heat pump installations are complex and expensive, requiring a detailed technical and economic feasibility study. The rewards for heat pump deployment, however, can be impressive.

Heat pumps are often applied in combination with other means of conserving energy to improve overall efficiency even further.

Vapour recompression

Vapour recompression systems upgrade the thermal content of low-temperature vapours by one of two methods:

- **Mechanical vapour recompression (MVR)** – Centrifugal or positive displacement compressors are used to raise the pressure (and thus the temperature) of a vapour stream.
- **Thermal vapour recompression (TVR)** – The temperature of a vapour stream is increased by injecting it with hotter vapour.

Multi-stage operations

Multi-stage operations derive greater energy efficiency through the energy cascading effect in applications that involve heating or cooling. Examples include the sugar, distilling, petrochemical and food industries. In evaporation, energy usage can be reduced by two thirds when a single-effect evaporation is replaced with triple-effect technology.

Absorption heat transformer

The **absorption heat transformer (AHT)** is the newest heat reclamation technology, which until now has been deployed mostly in Japan and Europe. As the difference between electrical energy and fuel prices grows, this technology will become more widely used in North America. The initial applications were in the rubber, brewing, alcohol, abattoirs and meat packing and ethyleneamine production industries; other opportunities are indicated for food, chemical and pulp and paper industries. Application in other industries is being assessed.

An AHT is driven by waste heat only (i.e. no primary energy is used except for a small amount of electricity needed to drive pumps). The transfer medium used is invariably a 60 percent solution of lithium bromide. AHTs have a remarkably rugged COP of about 0.45 to 0.48 and are practically unaffected by temperature conditions.

The COP indicates that about one half of the heat in a waste stream can be upgraded to a usable temperature level. Hence, AHTs are ideally suited to applications in which

- The supply of waste heat considerably exceeds the demand for heat at the higher temperature by a factor of at least two.
- The heat source should have a temperature of 60–130°C, with the heat output approximately 20–50°C higher. Heat can be upgraded to about 15 percent of the temperature gradient. The maximum possible value of heat demand level is approximately 150°C (because of corrosion concerns).
- Ideally, the heat source is in the form of latent heat and is available in abundance – in the megawatt range.

AHTs offer excellent performance even under partial load conditions. It can compete with a boiler and, primarily, with MVR. With due consideration of megawatt size of the installation, the AHT system is favoured economically in comparison with MVR when

- the electricity/fuel cost ratio is at or above three;
- the heat source has a temperature of approximately 100°C, with the heat output approximately 40–50°C higher; and
- there is less sensitivity to temperature conditions.

Simple payback periods of one to four years have been obtained.

A very important consideration that may well enhance the AHT application potential is the positive impact of the technology on the environment. As AHTs are driven by waste heat only, emissions from an industrial plant can be substantially reduced.

Energy management opportunities

Housekeeping EMOs

- Identify sources of waste heat.
- Eliminate as many sources of waste heat as possible.
- Reduce the temperature of remaining waste heat.
- Improve equipment inspection and maintenance to minimize the production of waste heat.

Low-cost EMOs

- Capture waste heat from a clean waste stream that is normally discharged to the atmosphere or drain by piping the waste stream to the point of use.
- Utilize the waste process water as a heat source for a heat pump.
- Utilize the heat of the plant effluent being treated in a wastewater treatment plant (where applicable) as a heat source for a heat pump.
- Re-use hot exhaust air for drying purposes.
- Install improved automatic controls.
- Consider re-using heat from cooling hydraulic oil circulating (e.g. within moulding machines and the injection moulds themselves); it reduces the electrical load on the production process as well.

Retrofit EMOs

- Install waste heat reclamation equipment (e.g. replacing a cooling tower circulation loop with a shell-and-tube heat exchanger).
- Consider upgrading or replacing outdated waste heat reclamation equipment.
- Consider combining a flue gas heat recuperator with a heat pump and neutralization of an alkaline effluent by the flue gas.
- Consider deploying AHTs.
- Consider installing a CHE and integrating it with other processes.
- In a large computer centre, consider capturing the heat generated by, for example, using cold and hot thermal storage, or by using a double-bundle turbo refrigerator to recover the heat generated by refrigeration.
- Consider converting high-temperature flue gas heat (e.g. from metallurgical furnaces) into superheated steam for steam turbine power generation.

Environmental considerations

Recovered, re-used heat displaces heat generated with purchased energy. For example, by displacing steam generated in a boiler, recovered heat reduces boiler emissions by reducing the requirement for fuel. Also, the environmental benefits of using AHTs have already been described. See Section 1.1, "Climate change," on page 1 for more information on calculating emissions reductions resulting from energy efficiency improvements.

More detailed information

The comprehensive technical manual *Waste Heat Recovery* (Cat. No. M91-6/20E, available from NRCan) provides a usefully detailed understanding of the subject. See page vi of the preface of this Guide for ordering information.

Waste heat recovery evaluation worksheet

Boiler stack exhaust

Use the evaluation worksheet in Section 2.5, "Boiler plant systems," on page 83.

HVAC system

Use the evaluation worksheet in Section 2.8, "Heating, ventilating and air-conditioning systems," on page 102.

Refrigeration and heat pumps

Use the evaluation worksheet in Section 2.9, "Refrigeration and heat pump systems," on page 112.

Process furnaces, dryers and kilns

Use the evaluation worksheet in Section 2.16, "Process furnaces, dryers and kilns," on page 163.

Exhaust air

Check the temperature and flow rate of exhaust fan discharge.

Can the air be ducted directly into another area for space heating?

☐ Yes — As soon as possible, install ducts and a blower to move air into the area to be heated.

☐ No — Consider preheating make-up air or recovering heat with an air-to-air heat exchanger.

Done by: ______________________ Date: ______________________

Waste water

Inventory all process water streams that leave the facility.

Are any process water streams warmer than 38°C when they leave the facility?

☐ Yes — Consider installing a heat exchanger to recover heat for use in process or space heating.

☐ No — If the wastewater flow is large, a heat pump or an AHT may be appropriate (consult an engineer).

Done by: ______________________ Date: ______________________

Cooling water

Survey plant processes, noting those that require cooling water.

Is cooling water dumped into a drain?

☐ Yes — If possible, consider using the warm water directly in another process. Consider using a heat exchanger to recover heat for another process.

☐ No — If cooling water is sent to a cooling tower, consider replacing the cooling tower with a heat exchanger to recover heat from the water for other processes.

Done by: ______________________ Date: ______________________

Water vapour exhaust

Survey plant processes for those that emit large amounts of water vapour (e.g. evaporators, kettles with direct-steam injection heating).

Does any equipment exhaust a large amount of water vapour?

☐ Yes — Consider using either mechanical or thermal vapour compression to upgrade the exhaust vapour into a more useful energy source.

☐ No — No action required.

Done by: ______________________ Date: ______________________

Note: Add further questions to this evaluation worksheet that are specific to your facility.

2.18 Combined heat and power (CHP – "cogeneration")

The units for the simultaneous production of heat and power achieve much greater efficiencies than in the case of separate generation, giving primary fuel savings of 35 percent, with overall efficiencies of 85 percent and more. Combined heat and power (CHP) systems employ a single unit to produce electricity and heat or sometimes provide shaft power to drive other equipment. They can be economical in situations where heat at an appropriate temperature level is required and a demand for power also exists. The energy efficiency aspect of CHP and its environmental benefits in reduction of CO_2 and NO_x emissions are reasons for a mounting interest in this rapidly developing technology. The following outlines the technology and some of the EMOs. See Table 2.5 on page 174 for CHP comparisons.

The first-generation CHP plants have been around for decades – in Denmark, 48 percent of power demand and 38 percent of heat demand were supplied by CHP plants in 1996. However, the restructuring of energy generation in a few provinces of Canada is making it easier for the industry to contemplate CHP installations with the option of selling surplus electricity to the power distribution grid. Other provinces are working on or studying deregulation.

A CHP unit typically consists of a prime mover – for generation of electricity – and a heat recovery steam generator.

Before a decision on CHP project initiation can be made, there must be adequate knowledge of the following:

- the electrical and thermal load profiles of the facility that also take into account seasonal variations;
- the price relationship between electricity and fuel;
- the potential for energy conservation and energy efficiency projects;
- the outlook for future energy demand of the facility; and
- investment costs involved and possible financial incentives/assistance.

This will help in selecting the type of prime mover for the system and in selecting the appropriate size. The greatest energy efficiency is obtained when a unit is operating at full load. Hence, situations of extended part-load operation or long shutdowns that may result from using an oversized unit should be avoided.

Technology

CHP systems are evolving rapidly, and manufacturers offer units that have a great range of outputs, from tens of MW all the way down to the 1-kW level. A lot of effort is devoted to the development of small-scale CHP technologies. They are based mainly on the Rankin or steam turbine cycle, reciprocating engine cycle or gas turbine cycle.

Tip

If uncertain about the demand level, select a smaller unit – probably at 50 percent of the site's maximum thermal demand, with additional heat demand being met by conventional boilers. That will ensure high utilization rates of the CHP unit.

TABLE 2.5
Small-scale CHP comparisons

Technology	NO_x (ppm)	Efficiency (%)		
		Heat	Electric	Total
1 MW natural gas turbine	<20	60–65	20–25	85–90
1 MW natural gas reciprocating engine	108	50	35–40	85–90
New, utility-sized combined cycle gas turbine (no transmission and distribution)	n/a	n/a	55	55
Current power grid (including transmission and distribution)	n/a	n/a	30	30
New industrial gas boiler	24	85	n/a	85
Average installed industrial boiler	120	65	n/a	65
Back pressure steam turbine	n/a	65	7–20	75–85
Fuel cells	0.05	–	50	–

Gas and steam turbines are better suited to industries where a steady and high demand for high-pressure steam exists, such as in wood and paper and petrochemical facilities. Gas engines are used mostly for <1–3 MW installations in industries that have a demand for low-pressure steam and/or hot water, such as in the food industry. Steam turbines are used in locations where steam surplus to demand is available.

The energy source is mainly natural gas, although waste, biomass, biogas, diesel, gasoline, coal and oil may be used in some installation configurations. The power-to-heat ratio of generation is improving, from the earlier value of 0.5 to the current 0.6-0.7 and is still rising, toward 1.0, for a total efficiency of 80 percent. The simple paybacks for CHP installations may range from $1^{1}/_{2}$ to 10 years, with $4^{1}/_{2}$ years being the average.

Improvements in automatic monitoring and controls enable most CHP systems to operate without any permanent staff at the plant; one person can look after several units.

The biggest potential of CHP systems is in replacing the thousands of small, aging boilers throughout Canada with units that produce both power and heat with greater efficiency. As well, companies that have power needs in the range of 300 kW to 1 MW and that must replace their outdated chillers are an important growth segment. For example, market estimates in the United States call for multi-billion-dollar sales of CHP systems by the year 2010.

Tip

Consider installing more than one CHP unit – or adding thermal storage to the design – to ensure high utilization level of the installation and its flexibility in maintaining full-load conditions for the highest energy efficiency.

New developments are notable in gas microturbines (output of 500 kW or less) and fuel cells. Their compact size offers the possibility to eliminate transmission and distribution losses by locating the power/heat source close to the point of intended use.

The capital costs of microturbines currently well exceed those systems that have reciprocating engines as prime movers. The higher initial cost of these systems is offset, however, by their virtually maintenance-free design. Also, their overall efficiency is further increased because the turbine, compressor and permanent magnet are mounted on a single shaft, avoiding mechanical losses.

The fuel cells convert chemical energy directly into electricity. They are virtually non-polluting, quiet and have low maintenance requirements. Industrial installations include 200 kW phosphoric acid fuel cells and the recently introduced 250 kW proton exchange membrane power unit. Although the heat output is relatively low grade (80°C), future increases of up to 150°C are expected, which should allow easier steam generation.

Energy management opportunities

Housekeeping EMOs

- Ensure regular inspection and preventive maintenance.

Low-cost EMOs

- Analyse your current heat and power demand situation and perspectives; evaluate the economic potential of a possible CHP installation.
- Add an economizer for feedwater preheating to improve total efficiency.

Retrofit EMOs

- Install a CHP unit.
- Upgrade your CHP installation to a combined cycle where, for example, steam is expanded in a steam turbine to produce additional electricity.
- Complement your CHP with daytime (diurnal) heat storage to improve electricity production and its profitability during high-tariff and peak demand periods for use against subsequent demand.
- Consider alternative uses of CHP where the unit's shaft is used to drive other equipment (e.g. refrigeration compressor, HVAC compressor or air compressor) instead of using a steam generator.
- Consider using the recovered heat through an absorption chiller for cooling purposes instead of water heating or for air heating for dryer or space heating.
- Consider integrating your CHP with a heat pump to utilize a low-temperature heat source for a highly energy-efficient system.

Tip

Improve your electricity revenue and thus the economy of the plant by adding thermal storage capacity (usually worth 10 hours during daytime) to the CHP. Heat storage improves electricity production during high-price / peak-demand periods by storing heat against future demand.

Tip

A steam expander driven by high-pressure steam from the waste heat boiler of a CHP may be installed to produce compressed air for the facility. The low-pressure steam from the expander may further be used for other processes.

Environmental considerations

CHP is clearly an important environmental improvement over existing power generating, heating and cooling technologies. CHP plants have been proven to contribute to significant reductions of overall CO_2 generation. Also, lower NO_x levels are achieved with some form of control incorporated in most instances (e.g. lean burning, or based on catalytic reduction techniques using urea or ammonia). See Section 1.1, "Climate change," on page 1 for more information on calculating emissions reductions resulting from energy efficiency improvements.

The use of acoustic enclosures can reduce noise levels from turbines or engines from about 100 dB(A) to well below the typical legislated limit of 85 dB(A).

More detailed information

Further information is available from Natural Resources Canada's Office of Energy Efficiency Web site at http://oee.nrcan.gc.ca. Other Internet sites can also be valuable resources.

2.19 Alternative approaches to improving energy efficiency

Innovation, imagination and creativity are the hard-to-define but essential ingredients in the quest for energy efficiency improvements. With some imagination, a solution known in one field may be creatively and innovatively applied in another area. The world is full of successful energy conservation stories, yet few people know about them. The following few points are offered to stimulate thinking and whet our appetite for learning more.

Renewable energy

Consider using one of the following:

- a micro-hydro generating station in Canadian northern and remote locations. A small dam on a creek to hold eight to 10 hours of full load production and a Pelton turbine with an alternator and a voltage/frequency regulator may prove to be an economic alternative to a diesel generator;
- solar heat from the factory attic to heat below-ground storage space via a ventilation system; and
- wind-generated power to supplement the grid-supplied electricity and to promote "green" energy use, as a major carpet manufacturer in Canada is doing.

Wastewater treatment plant (WWTP) EMOs

Consider the following:

- recovering latent heat from plant effluent and/or WWTP mixed liquor, especially where anaerobic systems exhibit higher temperatures;
- using biogas from the anaerobic WWTP to supplement the factory's energy needs;
- reviewing dissolved oxygen levels in aerobic WWTP and the method or aeration (replace inefficient aeration equipment with a fine-bubble dispersal method. Could a waste oxygen stream be utilized if available?); and
- installing an aeration optimization control system to reduce blower energy use costs.

Miscellaneous – Where applicable

- Installing a micro-filtration process may help in recovering rather than dumping large volumes of liquid (and the heat contained therein) for re-use.
- Use waste heat from a CHP exhaust to heat greenhouses (could you establish them as your business sideline venture?) and use the exhaust CO_2 to stimulate plant growth.
- An increase in the number of steps (effects) in an evaporation process may improve energy efficiency economically.
- The installation of compact immersion tubes to heat pasteurizers, bleachers, soakers, blanchers, bottle washers, etc. could replace inefficient indirect heating.
- Consider replacing a pneumatic conveying system with a mechanical conveyor.

For these and many other energy-saving ideas, information is available from the Web site at http://oee.nrcan.gc.ca, from the resources mentioned elsewhere in this Guide and from other sources on the Internet.

appendix a

Global warming potential of greenhouse gases

Greenhouse gas	Chemical formula	Global warming potential*
Carbon dioxide	CO_2	1
Chloroform	$CHCl_3$	4
HFC-23	CHF_3	11 700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134	$C_2H_2F_4$	1000
HFC-134a	CH_2FCF_3	1300
HFC-152a	$C_2H_4F_2$	140
HFC-143	$C_2H_3F_3$	300
HFC-143a	$C_2H_3F_3$	3800
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-245ca	$C_3H_3F_5$	560
Methane	CH_4	21
Methylene Chloride	CH_2Cl_2	9
Nitrous Oxide	N_2O	310
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	$c\text{-}C_4F_8$	8700
Perfluoroethane	C_2F_6	9200
Perfluorohexane	C_6F_{14}	7400
Perfluoromethane	CF_4	6500
Perfluoropentane	C_5F_{12}	7500
Perfluoropropane	C_3F_8	7000
Sulfurhexafluoride	SF_6	23 900
Trifluoroiodomethane	CF_3I	<1

* 100-year time horizon.

Source: Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change.* (Cambridge, UK: Cambridge University Press, 1996), Table 2-9, "Radiative Forcing of Climate Change," p. 120.

CO_2 represented 76 percent of 682 Mt of Canada's total emissions in 1997. Since most of the gas is generated by combustion of fuels, whether for industrial, transportation, domestic or power generation purposes, the application of energy efficiency measures, which reduce fuel consumption, is an important way to reduce CO_2 emissions.

appendix b

Energy units and conversion factors

Basic SI units

Length	metre (m)
Mass	gram (g)
Time	second (s)
Temperature	Kelvin (K)

Commonly used temperature units

Celsius (C), Fahrenheit (F)

0°C = 273.15 K = 32°F

1°F = 5/9°C

1°C = 1 K

Fahrenheit temperature = 1.8 (Celsius temperature) + 32

Note: The use of the term "centigrade" instead of "Celsius" is incorrect. It was abandoned in 1948 to avoid confusion with a centennial arc degree used in topography.

Multiples

10^1	deca (da)
10^2	hecto (h)
10^3	kilo (k)
10^6	mega (M)
10^9	giga (G)
10^{12}	tera (T)
10^{15}	peta (P)

Fractions

10^{-1}	deci (d)
10^{-2}	centi (c)
10^{-3}	milli (m)
10^{-6}	micro (µ)
10^{-9}	nano (n)

Derived SI units

Volume:	hectolitre (hL)	(100 L)
	cubic metre (m^3)	(1000 L)
Mass:	kilogram (kg)	(1000 g)
	tonne (t)	(1000 kg)
Heat:	Quantity of heat, work, energy	joule (J)
	Heat flow rate, power	watt (W)
	Heat flow rate	watt/m^2
	U-value	watt/m^2K
	Thermal conductivity	W/mK
Pressure:	Pascal (Pa)	

Conversion factors

	Multiply:	by	to obtain:
Length	metre	3.2808399	feet
	metre	39.370079	inches
Mass	kg	2.2046226	pounds
	tonne (t)	0.9842206	tons (long)
	tonne (t)	1.10233113	tons (short)
Volume	L	0.219975	gallons (imperial)
	L	0.035315	cubic feet
Energy			
Quantity of heat	kWh	3.6	MJ
	kWh	3412	Btu
	MJ	947.8	Btu
	Btu	0.001055	MJ
Heat emission or gain	W/m^2	0.317	Btu/sq. ft.
Specific heat	kJ/kgK	0.2388	Btu/lb. °F
Heat flow rate	W	3.412	Btu/h
U-value, heat transfer coefficient	W/m^2K	0.1761	Btu/sq. ft. h °F
Conductivity	W/mK	6.933	Btu in./sq. ft. h °F
Calorific value (mass basis)	kJ/kg	0.4299	Btu/lb.
Calorific value (volume basis)	MJ/m^3	26.84	Btu/cu. ft.
Pressure	bar	14.50	lbf/sq. in. (psi)
	bar	100	kPa
	bar	0.9869	std. atmosphere
	mm Hg (mercury)	133.332	Pa
	ft. of water	2.98898	kPa
Specific volume	m^3/kg	16.02	cu. ft./lb.
Velocity	m/s	3.281	ft./s

Useful values

1 Therm = 100 000 Btu or 29.31 kWh
1 cu. ft. of natural gas = 1 000 Btu or 0.2931 kWh
1 m^3 of natural gas = 35 310 Btu or 10.35 kWh
1 U.S. gal. No. 2 oil = 140 000 Btu or 41.03 kWh
1 imperial gal. No. 2 oil = 168 130 Btu or 49.27 kWh
1 U.S. gal. No. 4 oil = 144 000 Btu or 42.20 kWh
1 imperial gal. No. 4 oil = 172 930 Btu or 50.68 kWh
1 U.S. gal. No. 6 oil = 152 000 Btu or 44.55 kWh
1 imperial gal. No. 6 oil = 182 540 Btu or 53.50 kWh
1 boiler horsepower = 33 480 Btu/h or 9.812 kW
1 mechanical horsepower = 2 545 Btu/h or 0.7459 kW
1 ton refrigeration = 12 000 Btu or 3.5172 kWh

In Canada, the value of 1 Btu (60.5°F) = 1.054615 kJ was adopted for use in the gas and petroleum industry. The ISO recognizes the value of 1.0545 kJ.

appendix c

Technical industrial publications available from the Canada Centre for Mineral and Energy Technology (CANMET)

Please copy the form below, fill in the required information and fax to the number indicated.

CANMET

CANMET Energy Technology Centre
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Technical industrial publications

1. *Low NO_x Demonstration Project* – 1991
2. *Processes, Equipment and Techniques for the Energy Efficient Recycling of Aluminum* – 1993
3. *Research and Development Opportunities for Improvement in Energy Efficiency in the Canadian Pulp and Paper Sector to the Year 2010* – 1993
4. *Present and Energy Efficiency Future Use of Energy in the Cement and Concrete Industries in Canada* – 1993
5. *Present and Future Use of Energy in the Canadian Steel Industry* – 1993
6. *Energy Efficiency and Environmental Impact for the Canadian Meat Industry* – 1993
7. *Energy Efficiency R&D Opportunities in the Mining and Metallurgy Sector, Phase 1 – Scoping Study* – 1993
8. *Energy Efficiency R&D Opportunities in the Food and Beverage Sector, Phase 1 – Scoping Study* – 1993
9. *Energy Efficiency R&D Opportunities in the Oil and Gas Sector, Phase 1 – Scoping Study* – 1993
10. *Technical Specifications for an Energy Management System* – 1993
11. *Technical and Market Study of a High Temperature Heat Pump Applied to Paper Machine Dryer Heat Recovery* – 1993
12. *Chemical Pulp Bleaching: Energy Impact of New and Emerging Technologies* – 1994
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14. *Energy Efficiency for the Canadian Seafood Processing and Aquaculture Industries* – 1994
15. *Prospects for Energy Conservation Technologies in Canada – The Steel Industry Position* – 1994
16. *Low NO_x Technology Assessment and Cost/Benefit Analysis* – 1994
17. *Application of Artificial Intelligence Technology to Increase Productivity, Quality and Energy Efficiency in Heavy Industry* – 1995
18. *Energy Efficiency Process for the Pulp and Paper Industry: Analysis of Selected Technologies* – 1995
19. *Gas Utilization and Operations RD&D Needs, Activities and Technology Enablers: Baseline Data for CGA's Natural Gas Technology Development Plan* – 1995
20. *Mid-Kiln Injection of Tire-Derived Fuel at Lafarge Canada Inc. Cement Plant at St-Constant, Quebec* – 1995
21. *Natural Gas Applications for Industry – Final Report – Beverage Industry* – 1996
22. *Natural Gas Applications for Industry – Final Report – Cement Industry* – 1996
23. *Natural Gas Applications for Industry – Final Report – Chemical Fertilizers* – 1996
24. *Natural Gas Applications for Industry – Final Report – Dairy Industry* – 1996
25. *Natural Gas Applications for Industry – Final Report – Feed and Alfalfa Industry* – 1996
26. *Natural Gas Applications for Industry – Final Report – Food Processing Industry* – 1996
27. *Natural Gas Applications for Industry – Final Report – Hydrogen* – 1996
28. *Natural Gas Applications for Industry – Final Report – Industrial Chemicals* – 1996

29. *Natural Gas Applications for Industry – Final Report – Iron and Steel Foundries* – 1996
30. *Natural Gas Applications for Industry – Final Report – Meat and Poultry Industry* – 1996
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32. *Natural Gas Applications for Industry – Final Report – Overview* – 1996
33. *Natural Gas Applications for Industry – Final Report – Plastics Products* – 1996
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36. *Natural Gas Applications for Industry – Final Report – Sawmills* – 1996
37. *Natural Gas Applications for Industry – Final Report – Steel Industry* – 1996
38. *Natural Gas Applications for Industry – Final Report – Vegetable Oils* – 1996
39. *Natural Gas Applications for Industry – Wood Board Industry* – 1996
40. *Helical Grooved Pulpstones Research and Development Project, Final Report* – 1996
41. *Modeling of Black Liquor Recovery Boilers, Summary Report* – December 1996
42. *Market/Technical Evaluation of Natural Gas Technologies for Industrial Drying Applications in Food and Beverage Sectors* – 1996
43. *Implementation of an Effective Mill-Wide Energy Monitoring System* – 1996
44. *Advances in the Application of Intelligent Systems in Heavy Industry* – 1997
45. *Intelligent Energy Management for Small Boiler Plants – Metering, Monitoring and Automatic Control* – 1998

Fact sheets

Please circle the title required.

FS-1E	*Federal Industrial Boiler Program*
FS-2E	*Stone Groundwood Process Control*
FS-3E	*Energy Efficient Lumber Kiln*
FS-4E	*Water-Based Automotive Paints*
FS-5E	*Recycling Heat from Ventilation Air*
FS-6E	*Recovery of Phosphate Rejects*
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strengthens and expands Canada's commitment to energy efficiency
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